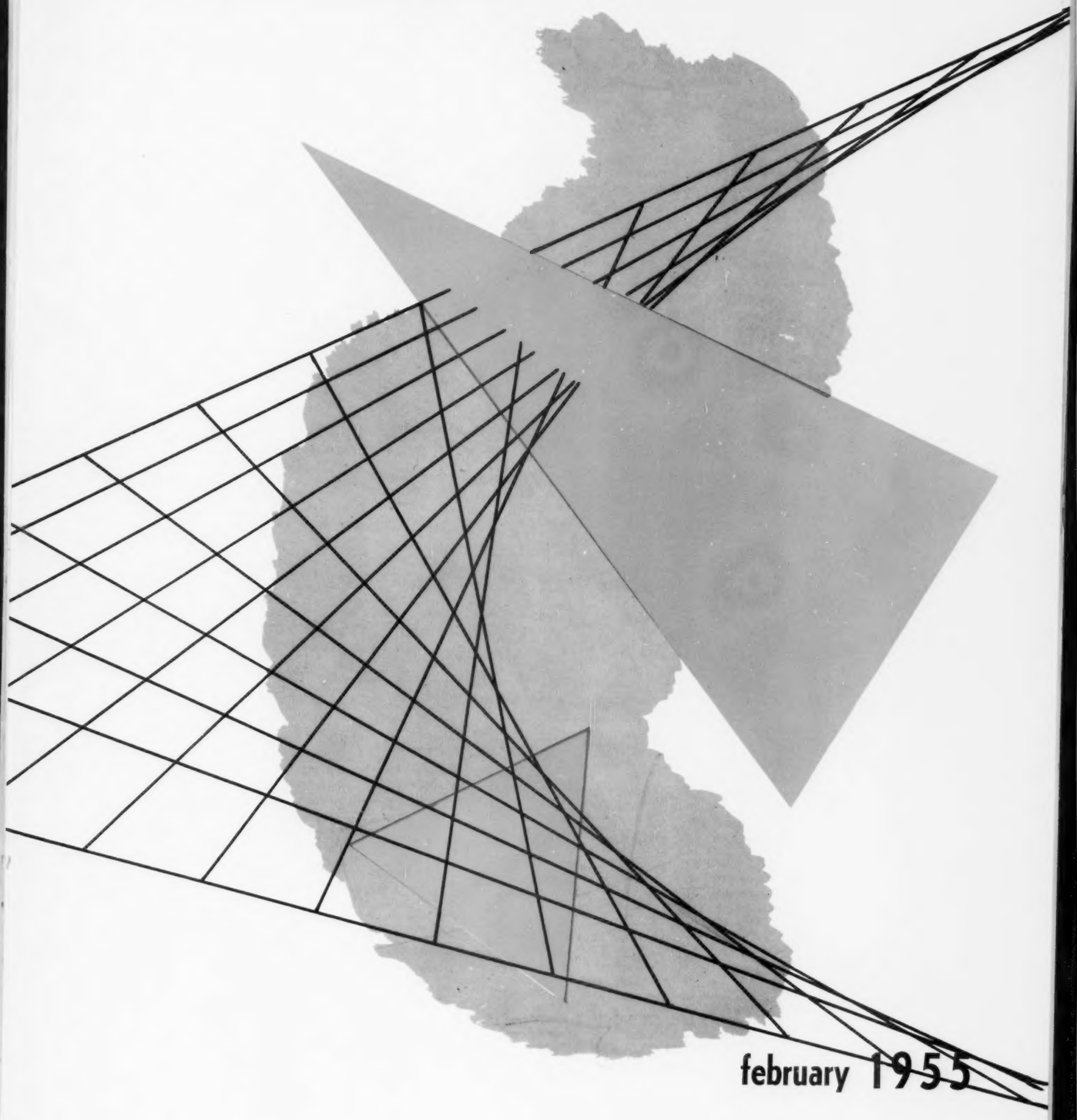
tech engineering news



february 1955

Sanford W. Wilson, class of '48
speaks from experience when he says . . .

"U. S. Steel offers a great combination—opportunity, security and an interesting job"

MR. WILSON was interviewed by U.S. Steel representatives in March of 1948. After receiving his B.S. in Chemical Engineering in June, he chose his U.S. Steel offer over several other job offers and began working at the huge Gary Works as a Foreman Relief Trainee. He gained experience in the Blast Furnace Department and in the front office learning the business end as well. In November of 1954 Mr. Wilson was made assistant to the superintendent of blast furnaces at Gary. His duties now include developing data for control of production, quality of materials, costs, and making technical reports. In addition, he directs the activities of Technological Co-Ordinators and part of the training of management trainees.

Mr. Wilson is naturally pleased with his progress at U.S. Steel and he feels that U.S. Steel offers qualified and ambitious engineers the very best in three important areas—opportunity, security *and* an interesting job.

He says, "Opportunity is unlimited at U.S. Steel and openings for advancement are frequent." In addition, Mr. Wilson feels that U.S. Steel affords a secure future because of the basic nature of the steel industry and the constant need for engineering talent. But most important, Mr. Wilson is deeply interested in his job because he knows he is really playing a vital role in a vital business. And he says, "The steel industry has many facets and is constantly changing. Talk to anyone who has been in the steel industry for any time and he will tell you that steel has gotten into his blood."

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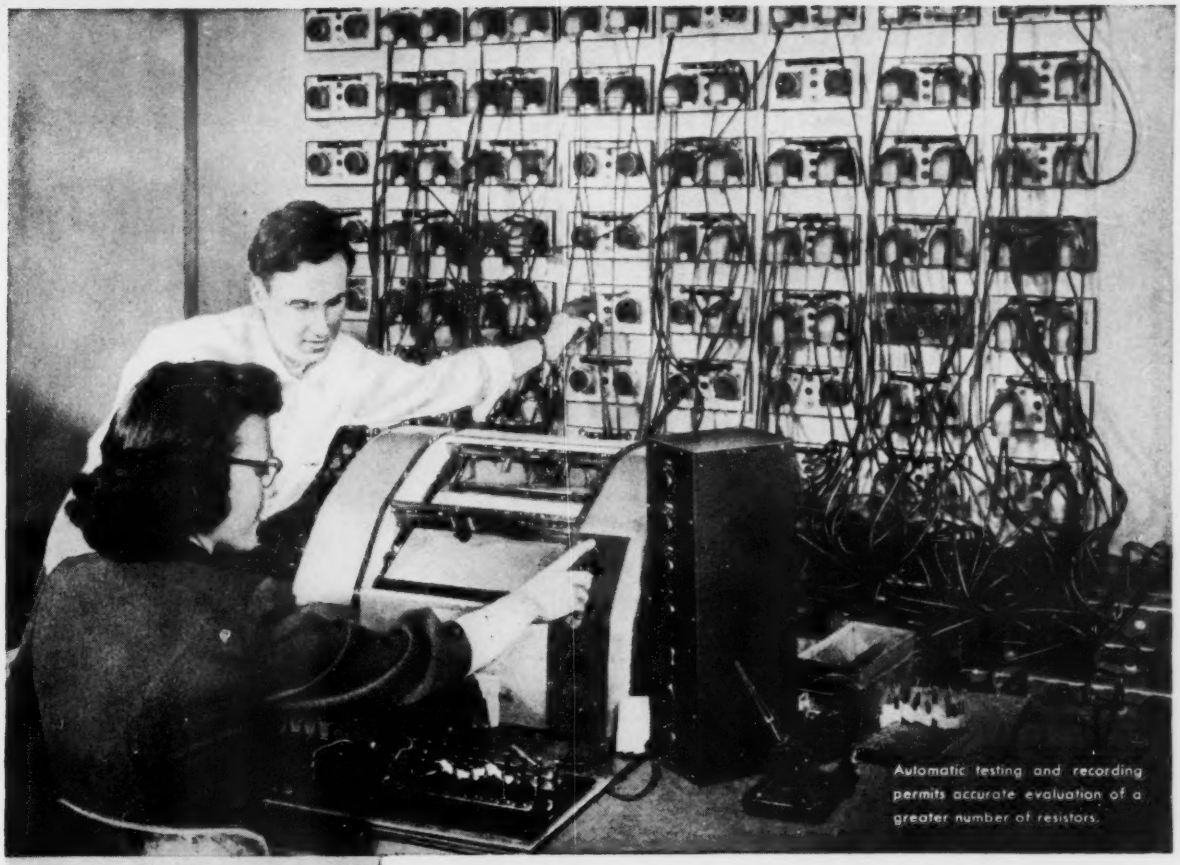

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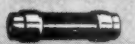
SPECIFIC EXAMPLES

Type BT Insulated Composition Resistors
MIL-R-11A Specification

IRC Power Wire Wound Resistors
MIL-R-26B Specification

Type BW Low Wattage Wire Wounds
JAN-R-184 Specification



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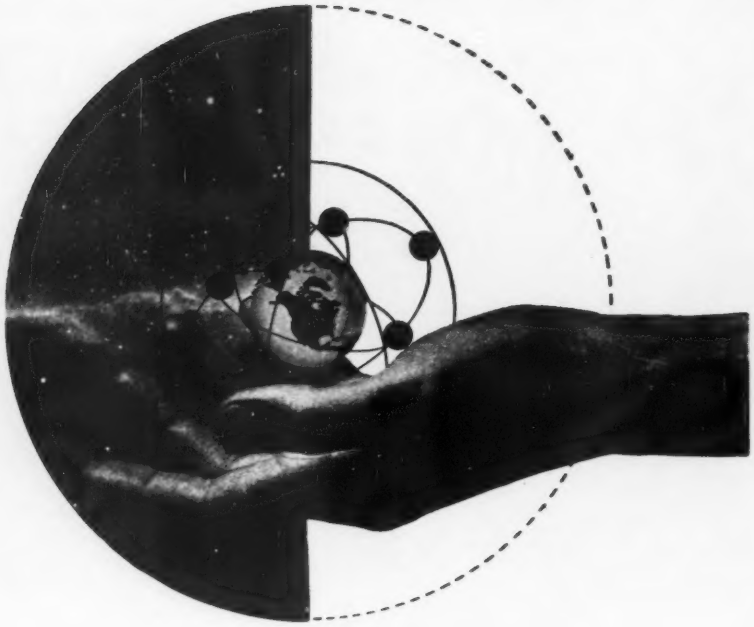

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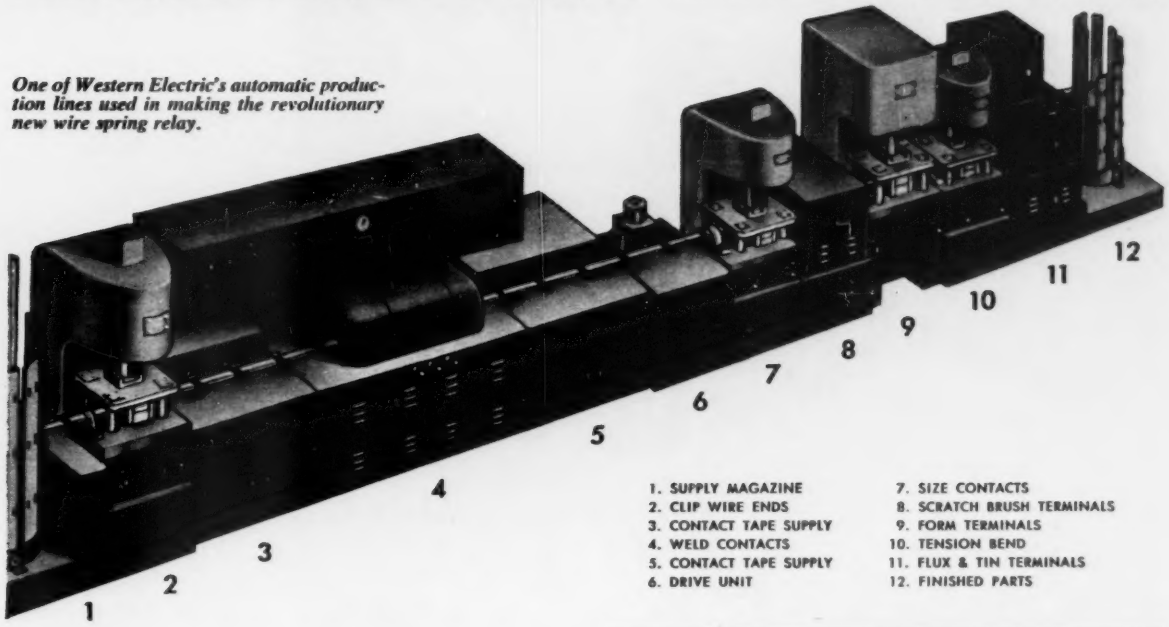
AUTOMATION at work

How a revolutionary new design was translated into a production reality

One of Western Electric's automatic production lines used in making the revolutionary new wire spring relay.



1. SUPPLY MAGAZINE
2. CLIP WIRE ENDS
3. CONTACT TAPE SUPPLY
4. WELD CONTACTS
5. CONTACT TAPE SUPPLY
6. DRIVE UNIT
7. SIZE CONTACTS
8. SCRATCH BRUSH TERMINALS
9. FORM TERMINALS
10. TENSION BEND
11. FLUX & TIN TERMINALS
12. FINISHED PARTS

So great was the departure in design of the new Bell System wire spring relay as compared with conventional relays that it posed a major undertaking for development engineers at Western Electric, the manufacturing and supply unit of the Bell System. Indeed, it was an undertaking that called for new machines and new methods because none was available to do the job.

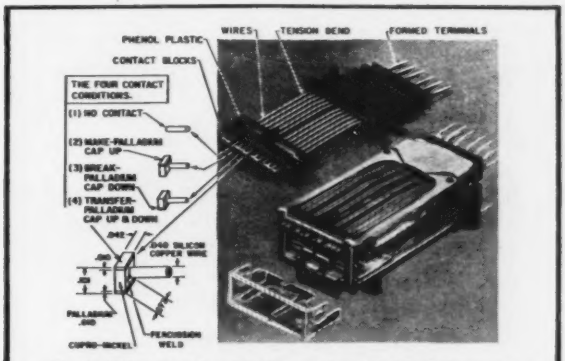
Longer life, higher operating speed, lower power consumption, and lower manufacturing cost were some of the advantages promised by the new relay design. Engineers reasoned that a lower manufacturing cost could be achieved through greater precision in manufacture (which would cut adjustments) and through extensive use of automatic processes.

One of the products of this reasoning is pictured at the top of this page. This battery of equipment, developed by Western Electric product engineers, constitutes one phase of wire spring relay manufacture, which automatically performs several separate operations. Its function begins after one of the fundamental elements of the new relay has been fabricated. This element, known as a "comb," consists of a multiplicity of small diameter wires in parallel array imbedded for part of their length in molded phenol plastic.

These molded elements, of which there are two types used in the new relay, are delivered to this line of machine units in magazines. By fully automatic means they are removed from the magazine, carried by a reciprocating conveyor through each of the several processes and, when completed, placed into another magazine to await further assembly.

Between the first and final magazine the automatic battery of equipment does the following operations: clips wire ends, attaches palladium contacts to wire ends by means of percussion welding, sizes contacts, forms terminal, tension bends wires, fluxes and tins terminals.

Most remarkable of all is the fact that this is a *precision* operation throughout. For example, the small block contacts, which are percussion welded to the tips of wires of one type of "comb," must be located on the same plane across the twelve contact positions to within a tolerance of ± .002".



Single Wire Comb with Percussion Welded Contacts, Wire Spring Relay Designed by Bell Telephone Laboratories

One type of "comb" element is shown at top while a completed wire spring relay is below. The small blocks of metal on the ends of the wires are cut from a composite tape during the automatic multiple percussion welding operation. "Contact conditions" are determined by the code of relay being manufactured and may vary greatly.

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

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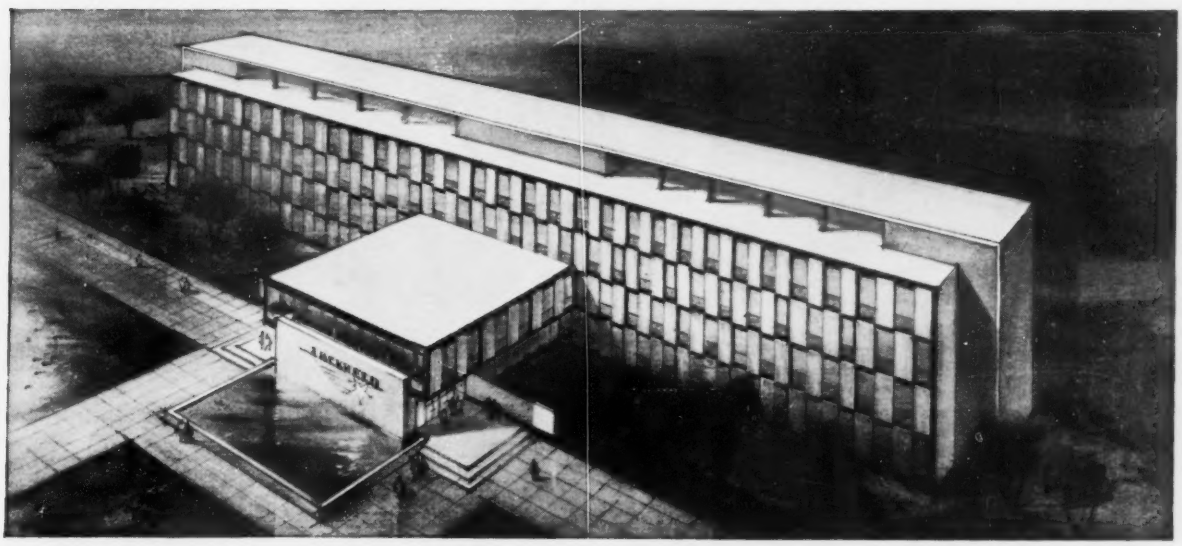
NEW MISSILE SYSTEMS RESEARCH LABORATORY

The technology of guided missiles poses increasingly complex problems in virtually every field of science.

To provide physicists and engineers with the most modern facilities for meeting those problems, Lockheed Missile Systems Division has begun construction on a laboratory for advanced research—first step in a $10,000,000 research laboratory program.

Scheduled for occupation in early fall of 1955, it will augment existing Missile Systems Division facilities.



Individuals able to make significant contributions to the technology of guided missiles are invited to contact their placement officer or write us.

Lockheed MISSILE SYSTEMS DIVISION

research and engineering staff

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tech engineering news

February 1955
Vol. XXXVI No. 5

The New Ether Theory 11
by Barry Mazur, '58

Editorial 21

Stereo Models Without a Stereograph 26
by D. F. Shraeder, '60

Climatic Control and the Causes of the Ice Age 31
by Hermatilda Klutz, Ph.D.

Special Theory of Relativity 38
by Neil MacFarlane, '58

Electrolysis 44
by Kenneth Mitzner

Cover Design by Bill Walsh, '57

FRONTISPIECE

Oblique photograph showing a glacier at the head of a fiord

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1927—Covering wing of early Boeing plane, Seattle plant

1955—B-47 Stratojet assembly, Boeing Wichita Division

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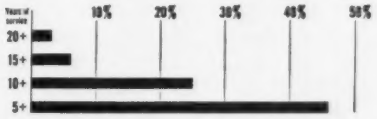
Throughout its 38-year history, Boeing has consistently pioneered advanced new types of military and commercial aircraft, and new methods of production. This history of leadership has meant continued growth for the company. It means continued opportunities for Boeing engineers to move ahead according to their ability in Research, Design and Production.

Today Boeing is producing the jet age's outstanding bombers, the B-52 and the B-47. Other Boeing projects that mean continued growth and stability include: America's first jet transport (the Boeing 707). Research in nuclear-powered and supersonic flight. And one of the nation's major guided missile programs. These and other new-horizon projects are expanding at such a rate that Boeing now employs more engineers than even at the peak of World War II.

The high inherent interest of these programs, together with the stimulation of expanding opportunities, add to the stability of careers at Boeing. One measure of stability is given in this chart.



It shows that 46% of Boeing engineers have been with the company for five or more years; 25% have been here 10 or more years, and 6% for 15 or more years. Another measure is the increasing proportion of engineers to total employees. Fifteen years ago the figure was one to 16. Today one out of each seven employees is an engineer.

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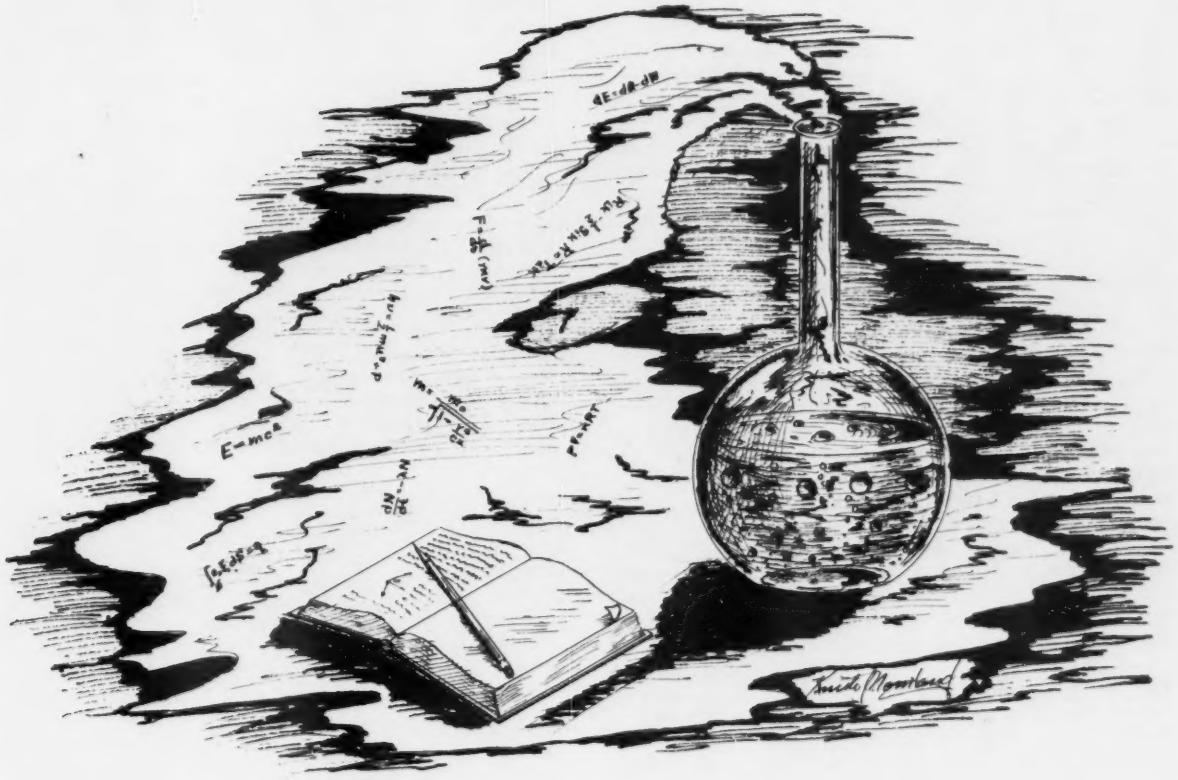
the new ether theory

by Barry Mazur, '58



Physics originated, as did all science, for the main purpose of answering a specific question that recurred in the thoughts of man. It owes its existence to the fact that man is intensely interested in the nature of his surroundings, and even more intensely bewildered by it.

How far has man penetrated the bewilderments of his universe, since the time he set out to explain it? That is a very broad question. A simple answer to it might be, not very far. It has not *settled* anything. To be sure it has unravelled some; it provides for us a very interesting view of the events in our universe; it ties one event in with another. The question I have just posed is very deceiving, for I do not intend to answer it, nor could I possibly answer it if I wanted to. What I hope to do is to examine the way in which physics "explains" simple phenomena; to bring up the not very profound question, *is* it explained? And in the light of that, to introduce a comparatively new theory as to the nature of the universe.

What is an explanation? It depends mostly on the sort of rules of the game that you allow. The basic rules or modus operandi of any science should be such as to motivate it towards answering the question it wants to settle. Let us begin with a simple example. Newton set out to find the motion of rigid bodies in space. That, in effect, was his basic problem, his point of departure. He considered himself to have solved the problem only after he was able to characterize and predict, so he thought, any type of motion when given appropriate data beforehand. Did Newton explain how rigid bodies move? Well, that depends entirely upon the level of penetration that you expect of an explanation. It depends upon how you want it explained.

The ancients were puzzled by the motion of an arrow through the air. How, they asked, could the arrow traverse the distance, if at any point during its flight it is at rest (for the moment it occupies that point)?

The answer to that question is not apparent.

Newton does not satisfactorily meet that particular problem either. That query, which owes its existence to Zeno, the Eleatic, has its roots in something deeper than the mere equations that describe *what* the arrow does. It points its finger toward the very meaning of velocity, displacement in space, and space itself. For how is the arrow carried along? Physics text books reply, "The body in question has a velocity or momentum." It must mean something, then, to have a velocity. What is it that bodies possess, to make them displace in space? Is it a fluid of some sort, that permeates the body? Certainly, one could not say that this property of the body, velocity, is inherent in it. The relative character of velocity is quite obvious to everyone. The confusion, then, is there; we do not have any notion of the manner in which an object traverses a distance in space. Furthermore if we expect the matter ever to be settled, we must choose that type of an explanation with which we would be satisfied. An explanation that would involve demons and ogres, clearly would not put the problem to rest forever in one's mind. Our explanation would be required to present the solution in terms of things that have been previously experienced by us. Hence, the terminology is very restricted. It is refined by the demands we place on an acceptable explanation.

Let us take another interesting example, for the moment. If a boulder is placed on a cliff, you may, by exerting a little effort persuade the boulder to go rolling down the cliff, rapidly picking up speed, and doing a tremendous amount of work before it finally comes to rest again. Physics answers the question posed there very simply. They reply that the boulder had a store of potential energy, which was used up as it went bounding over the cliff. What then is this potential energy that is stored up in things, and depend upon the position that the thing occupies? It seems to fit very neatly into the little system that physics has set up, the equations balance, but as an explanation, it is akin to one's attributing the movement of boulders to demons. Upon superficially examining an object, we may notice its color, scent, size, shape, hardness, etc., and come to the conclusion that we have exhausted all of the properties of that body. Physicists tell us that we are quite mistaken. There exist, over and above all directly sensible properties, those inpenetrables such as velocity, and potential energy stored up somewhere in it. There may be two points over which confusion originates. The first is in the terminology. There is no reason to expect the concepts that physicists deal with to be expressible in simple sentences. The second cause of confusion is in expecting this potential energy to reside in the body, or in some portion of the body. To do that would be to grant it a sort of concrete existence, something that a physicist would deny. The main point of consideration, however, is the fact that it is necessary, in order to "explain" the phenomena of the boulder, for physicists to "invent" certain concepts, and attach them to bodies as inherent properties of the body.

Let us go back to the paradox of Zeno. The paradox wishes to impress upon one the fact that if you were to take a snapshot of the arrow, at any position in its journey from one point to another, one would see the arrow perfectly at rest. How then did the arrow traverse the distance?

It requires a solution that transcends the concepts of velocity, or any other construction paper. It calls for something that appeals to the intuitions; it must be dealt with directly. It is almost as if there can be no acceptable explanation of it, for we demand too much of an explanation.

How rigidly shall we limit the use of impenetrable physical concepts in the explanation of the physical? By talking in terms of potential energy and velocity, and momentum, we are perfectly certain of their significance in mathematical terms, but we are very hazy of their actual meaning, their validity in the sphere of the concrete. To list as the cause of a physical phenomena, "momentum" of the object undergoing that phenomena, is to attribute the cause of a real happening. The concept doesn't exist. To be guilty of this is to open one's self to a whole barrage of philosophical interrogation as to the real nature of physical cause and effect. Can some concept which has no actual existence in the realm of physical objects exert a "real" effect on those objects? If it can, then under what mechanism is it operating?

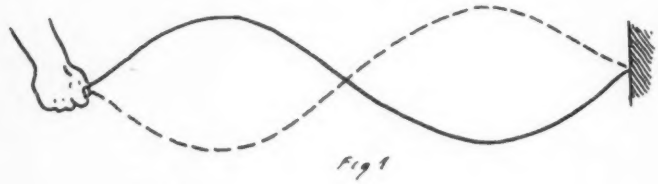


Fig 1

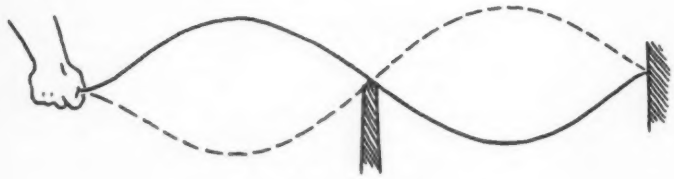


Fig 2

It can be seen at a glance that the problems such an "explanation" poses are even graver than the problem it actually set out to solve. When dealing, then, with such concepts, we must be very careful to subordinate them, never allowing them to assume a dominating role. It is the physically real, the concrete and only the concrete that can produce a real effect.

What happens, then, to the explanation of why the boulder bounds down the mountainside? It is not beyond repair, but it

rests on some shaky ground. First, a quality is attached to the boulder which is not too obvious—potential energy. Then this fictitious quantity is offered as the cause of the boulder's rolling down the mountain.

The above analysis detracts little or nothing from the fact that physicists have succeeded in finding out what happens. It is in the attempt to tie in observation and form an integrated system which satisfies the curiosity of man to know why; there is where progress is slow. One may say, that is not the job of the physicist. Rather is something to puzzle the philosopher. The quantum physicists such as Dirac, and Heisenberg, refuse to offer pictorial models of their conceptions of the physical universe. Why should the atom and the electron conform to any diagram? Why should man be so ego centered as to believe that the workings of the universe can be made understandable to his feeble mind? Why should there be an answer to the question—Why?

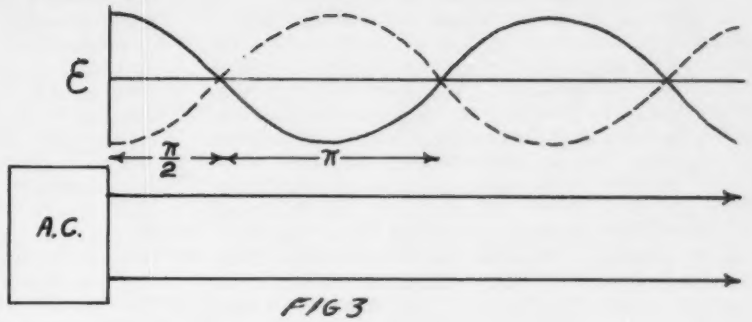


FIG 3

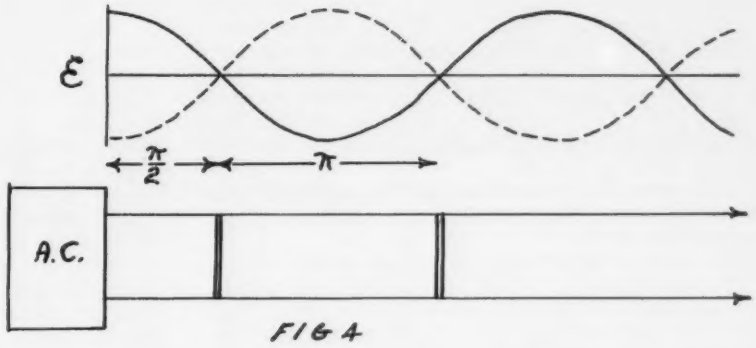


FIG 4

What is said may very well be true, but still the question remains unanswered, Why?

That we have accomplished little in the way of physical explanation points towards the difficulty of the task ahead for the physicist. If he restricts himself to just observation, and the recording of phenomena, he finds that he has a much easier job than if he were to seek the underlying reason for the occurrence of the phenomena.

Let me present the following physical problem. Suppose that a man was holding onto one end of a thin rope, the other end of which was fastened to a post. Suppose also, that he juggles the rope in such a manner that he produces a standing wave in the rope, as in fig. 1. The main characteristic of the standing wave is that there exists somewhere along the rope, a point that remains at rest. It is called a node. The entire rope oscillates, every point on the rope moves, except the node. Let us assume that while the man is juggling the rope in that manner, one supported the node-point by an exceedingly thin post, (fig. 2). Since the point is perfectly at rest, the appearance of the thin post supporting that stationary point should impede the motion of the rope in no way. The question I pose is this: The man is exerting energy to set the rope in motion. This energy is "transmitted" in some way throughout the length of the rope, to the other end. How does the energy get past the node-point of the rope? This involves the question: How does the energy get transmitted? An explanation to that would entail clearing up what is meant by energy being "transmitted". No one, unfortunately, has the answer. If we consider this concept, energy, to have any ability to be "transmitted" as modern physics does, then we are faced with the problem of what actually composes it, and where it resides, if it does at all. Is the energy, in that diagram, travelling inside the rope, or around the rope, or is this a meaningless question?

There is a close electromagnetic analog to this dynamic problem that I have posed. In a transmission line, there exists every half wave length along the line, a point at which there is no electric field, no voltage across the two wires. (The half wave length being of the frequency of voltage energizing the line.) (fig. 3). On those transmission lines it is possible to brige the two wires at the electric node-point with a metal bar, and the same electric, and magnetic field occurs past the node-point, (fig. 4). It is clear that the two events are very similar. The question that arises in both instances is how is the energy transmitted. It can be almost satisfactorily explained in the electromagnetic case by considering the energy to be contained in the electromagnetic field between, and around the wires, and not in the wires themselves. Of course, such an explanation is not free from loopholes, however, it is more successful than any theory has been to explain the dynamic counterpart. It becomes evident that we are to look for the solution of that dynamic problem in our mode of viewing energy, and its transmission.

A few years ago, the British philosopher, H. L. Samuel, introduced a new theory for the explanation of physical phenomena that seems to clear up this incident.

The New Theory

Dr. Samuel, in order to get around the philosophical contradictions of physicists delegating to non-existing concepts the power to operate upon the real world, postulated an ether. It is quite a simple postulate resorted to by physicists before but never with such interesting results. The Theory of Relativity as presented by Einstein considered matter to produce certain effects upon space. In brief, space was reshaped by the presence of matter. In order for this to be possible, says Dr. Samuel, space has to exist. There must be some substance, some interior construction of space to exist first, before any change in the structure can possibly be brought about. To answer, saying that space is composed of nothing, but is merely extension, is to deny that it can be acted upon in any way. In the light of that reasoning, Dr. Samuel maintained that space must consist of something. This something he named as "quiescent energy". Energy, postulated Dr. Samuel, exists in two forms; it exists in an activated form, such as light, heat, etc., and it also exists as a quiescent state, only exhibiting its existence when activated.

It is a simple assumption, on the surface. Let us see what the theory contributes in the way of explanations.

The theory says that the construction of energy is such that it exists in two distinct forms. The quiescent form pervades the atmosphere. The activated form is the energy about which we usually speak. Quiescent energy, which can be found throughout space, can be stirred up by an impetus into the activated variety. This quiescent energy is what we call ether. What about the "transmission" of energy? It will be remembered that this caused us a bit of trouble before. We were at a loss as to how to explain how, or what actually happens when energy is transmitted. Employing the two-state ether hypothesis, we can now attempt at some thing that may satisfy our curiosity somewhat. Energy transmission isn't really transmission any more. Using this theory, one could say that it consists of disturbances in the ether. Activated energy disturbing the quiescent energy adjacent to it into activity, carries the impulse along. That energy in turn activates the quiescent ether adjacent to it, and so on. Rather than considering any concrete substance to be moving from one point to another, as it appeared before, we now consider energy radiation to be just a change, an activation in the structure of space, where the *change itself* is the only thing that moves through space. The use of the word energy may lead to a bit of confusion, at this point. Dr. Samuel refers to this perturbation as energy. I believe, however, that it would be more profitable to think of both types of energy as merely manifestations of the inner *fabric* of space. Whatever this *fabric* may ultimately be discovered to consist of does not concern us. The main point for consideration is that modern relativity theory tacitly presupposes the existence of a structure in space. Rather than to disregard the fact, or attempt to explain inadequately, it should be worked in with The Theory, which is what Dr. Samuel has done.

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We are about to tackle the dilemma of motion, of momentum. When we propel an object, says Samuel, and the object traverses a distance, what moves the object? If it were a bird flying through the air, and we were asked this question, we might cursorily brush it off by saying that the bird moves *itself* through the air. The object, however, does not move itself; the object *is* moved. There must be something, then, between the point of departure, and the point of termination of the object to carry it; there must be something, some media to do this. Continuing on from there, one necessarily must postulate an ether.

What about the ether? What activates it? Why? Dr. Samuel adopts the theory that it requires a sort of minimum strength to activate the ether, something like a quantum of energy. If I throw a ball into the air, then, what I do is to set the ball in motion, whereupon it makes an impact on the portion of quiescent energy adjacent. If this impact exceeds the minimum, this activates the quiescent ether. The surrounding ether then in turn activates the quiescent ether beyond, and so on. This dynamic activation carries the ball onward through its path in space.

Let us return now to the question of the man juggling the rope. An explanation to it is much more easily forthcoming now. A mere application of the ether theory resolves it. It is set in motion by the exertion of the man, and the energy disturbation is carried along by the ether, which isn't bothered at all by the impediment of the fence-post. You'll notice that Professor Samuel's theory offers a solution to this problem that closely parallels the accepted solution of the electromagnetic counterpart.

As regards to potential energy, Dr. Samuel says in "Essay in Physics", "An ether theory would deny the existence of any 'store of potential energy' capable of being 'released', like water from a cistern when a tap is turned on. It would regard as meaningless, when applied to a passive object like a billiard ball, such terms as 'giving up' or 'transferring'."

The effect of gravitation, continues Samuel, is also due to radiation of quiescent energy disturbances. The difference between our boulder, when it occupied the position upon the cliff, and when it finally came to rest at the foot of the mountain, is that the ether disturbances due to gravitation were capable of operating on the boulder at one time, and are no longer capable of operating on it when it rests on the ground.

A phenomena that is brilliantly accounted for by the Samuel Theory is the Doppler Shift. It appears that the frequency of light rays coming from distant stars is shifted slightly to the red, the quantity of shift being proportional to the remoteness of the star. The hypothesis toyed with by physicist to explain this phenomena, called the Doppler Shift, is that all the stars are receding from each other at a rate that is proportional to the distance. Clearly, this isn't too satisfactory a theory, and many physicists never acceded to such a theory. If one attempts to explain it by way of ether, one would say that some minute quantity of energy is reverted to quiescence, as the disturbance gets carried along through space. In that, the frequency of a particle is directly associated with the energy of that particle of light, that accounts for the shift.

Objections to the theory are obvious. One may very well have recoiled in horror at the exposition of the theory with an exclamation something like this, "Say, if he believes in any of Einstein's stuff, he must consent to the fact that our meager conception of energy varies annoyingly with the speed of the observer." In a word, it's relative. If his ether, therefore, is energic, we might ask —"energic with respect to what? Is it quantitative? Is it motionless (awful word!) . . . He is terribly vague—He sounds like Democritus or someone."

In truth, the theory *is* terribly vague. The author *does* try to employ it as a panacea. He, of necessity, cannot shield the theory behind anything remotely resembling an iron-clad roof. The main accomplishment of the theory has been, however, to show that physics should, and can be made to make sense philosophically. It tries to dispell from the terminology of physics the remnants of mysticism, and to demand from it a more coherent and deeer approach toward physical explanation.

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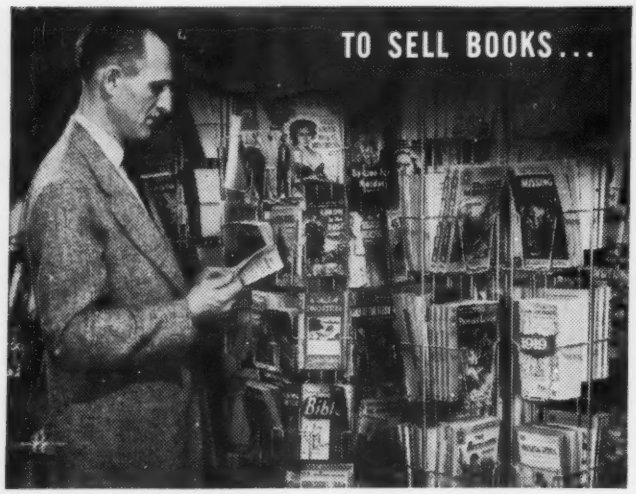

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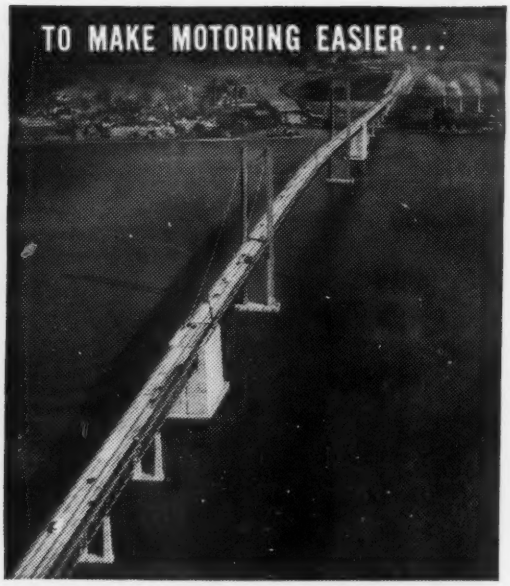

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from Donald C. Burnham, Vice-President
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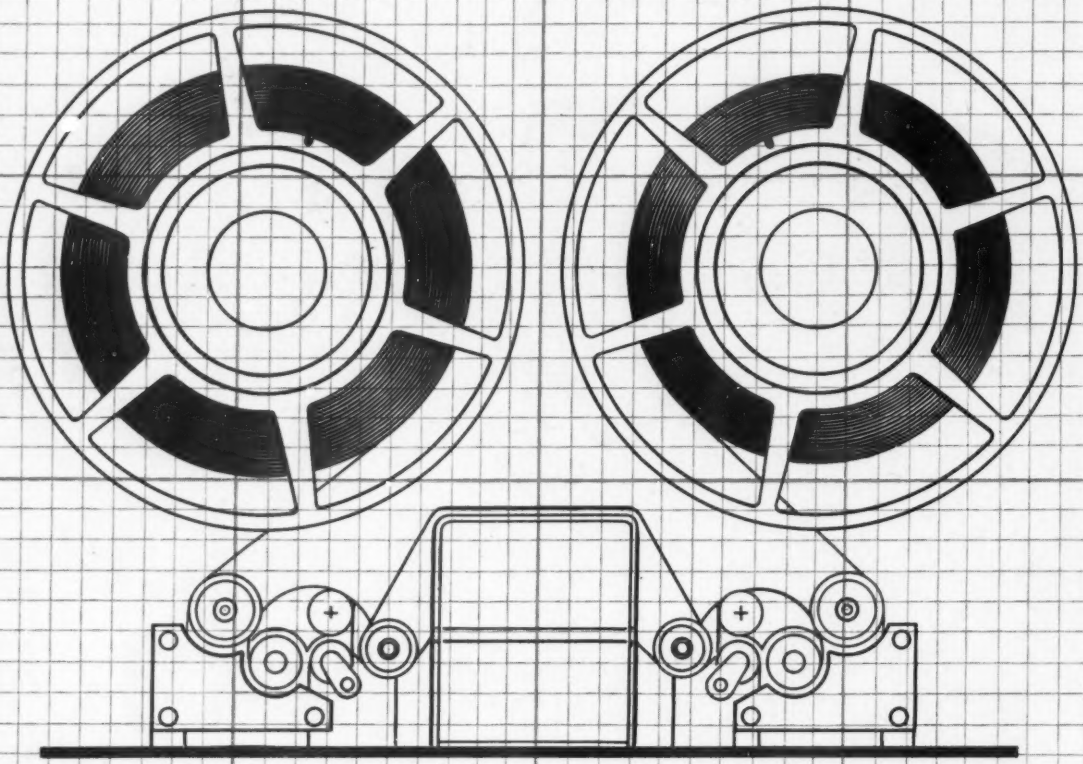

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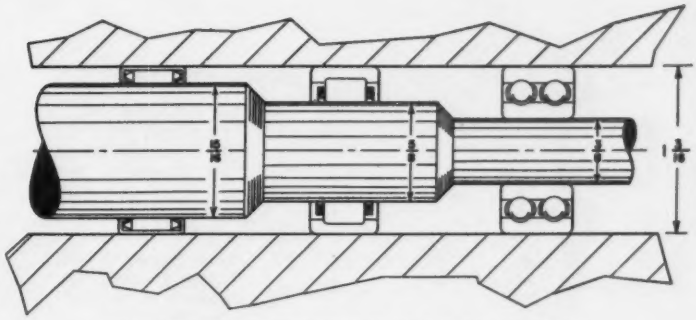

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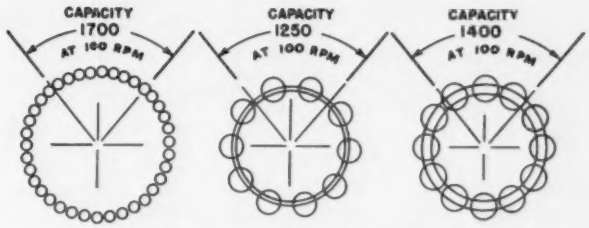

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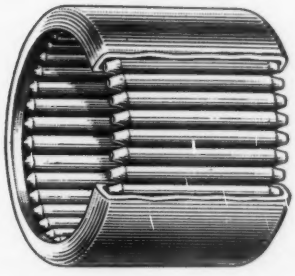

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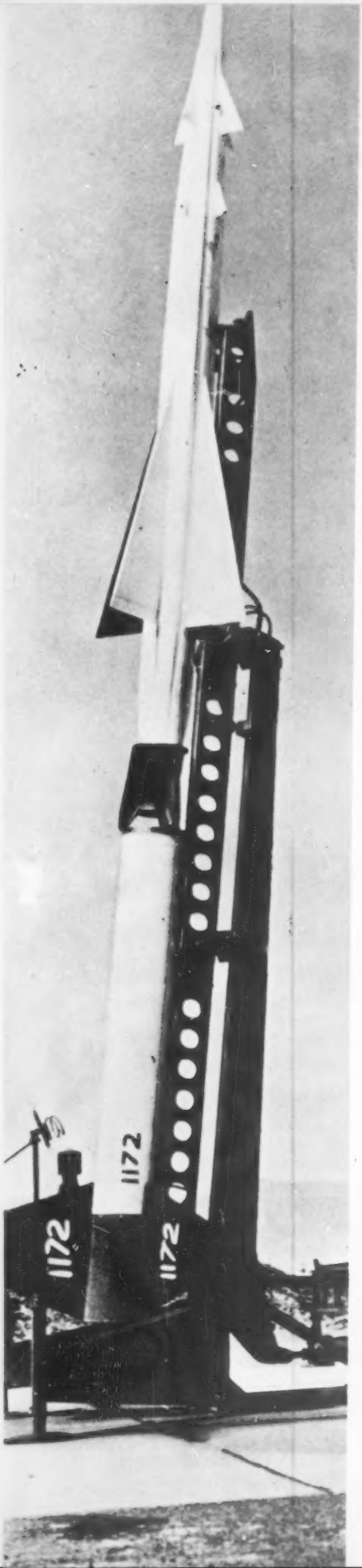

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from the editor's notebook

The "shortage of engineers" is just about as phony as a rubber ruble. Yet, a week never passes but some organization issues a press release or publishes a pamphlet bemoaning the lack of engineers and scientists. For several years the Engineering Manpower Commission of Engineers Joint Council has been publishing a Newsletter devoted solely to increasing the pool of engineering and scientific manpower. This group consistently takes the stand that there are not enough engineers, that enrollment of engineering schools should be increased, and that engineering students should be exempt from the draft. The Scientific Manpower Commission has just joined with the Engineering Manpower Commission in the publication of that newsletter.

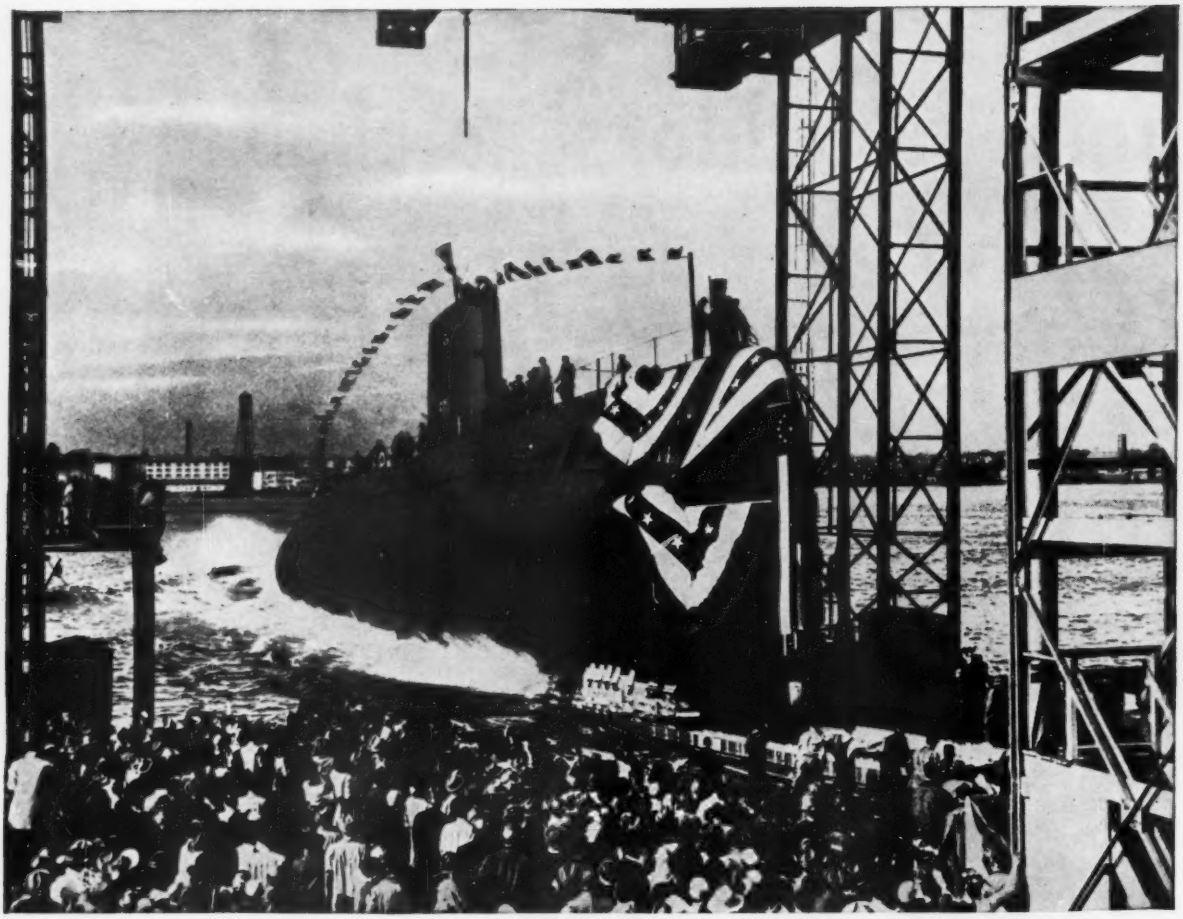
Now the National Association of Manufacturers is getting into the act. On January 22, the NAM issued a press release which begins, "Dear Editor: Our nation today is faced with a tragic shortage of scientists and engineers."

Tragic, indeed! The current shortage is not engineers, but coffee. The way we know there is a shortage of coffee is because the price of coffee has obviously risen in just six weeks. We have not noted a similar increase in the price of engineers in six months, or for that matter, in six years.

The coffee situation confirms our opinion that the law of supply and demand is still in effect. And we are convinced that the law applies to labor and the professions in just about the same way it applies to coffee. The difference is that coffee is paid for in cash, while engineers are paid in cash, professional prestige, and job security. Any employer who wants to test this statement need only place an advertisement in the classified section which states, "Wanted, Engineer for permanent position in strictly engineering work of professional caliber. Income equal to that of our corporation lawyer." The employer who placed such an ad would quickly reject the idea of a shortage of engineering talent.

It is a simple fact that if the price is right, the engineers are available. Currently, engineers have found that they can make more money in sales or management. On top of that, our own scientific societies are constantly encouraging young members to "progress" to management jobs rather than stick to professional engineering.

So far as we know, engineers are the only professional group idiotic enough to personally finance a major campaign to increase the number in their group while at the same time they sit around and gripe about low pay. The medical profession does not pay the American Medical Association to go around screaming about the shortage of doctors. On the other hand, hundreds apply for entrance to a medical school for every one student who is admitted. It is high time we instructed the Engineering Manpower Commission to "cease and desist." It is time we worked with our engineering schools to see that entrance requirements are made more stringent. Only in this way will the supply be such that those with a good engineering education can demand proper payment for professional services throughout their careers.



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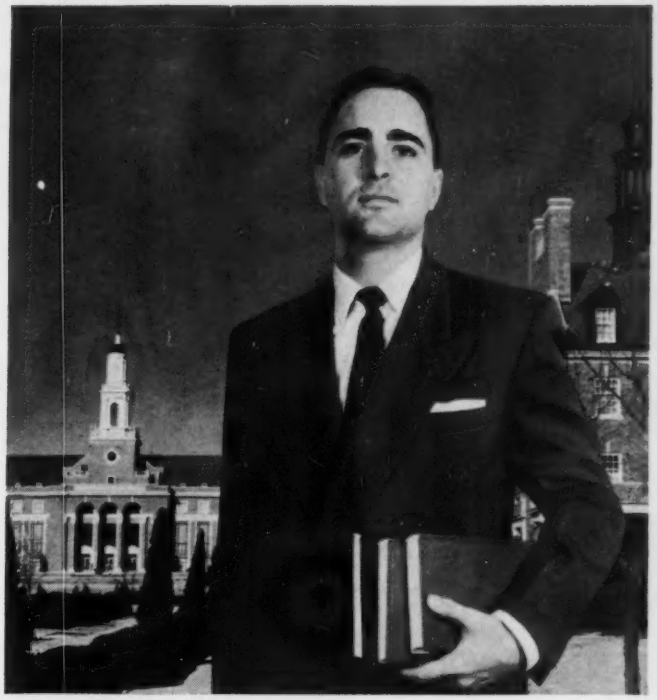

DRESSLAR M. PRUETT expects to receive his B.S. in Industrial Engineering this summer from Oklahoma Agricultural and Mechanical College at Stillwater, Okla. He is president of the local student branch of A.I.I.E. Naturally, he is interested in selecting the best job opportunity for a successful career based on his technical training.

DONALD C. MILLER received his B.S. in Chemical Engineering from Ohio State University in June 1937. During the following month he started work with the Organic Chemicals Department of Du Pont at Deepwater Point, N. J. Since then he has received and given many kinds of technical training. Today Don Miller is a general superintendent at Du Pont's Chambers Works—well qualified to answer questions about training programs for college men.

Don Miller answers:

Training has many facets in a big firm like Du Pont, Dress, and a great deal of thought has been given to make it truly effective. We look upon training as a very important factor in a man's career. We think that the best way to train a college graduate is to give him a maximum of on-the-job responsibility in a minimum length of time. That's the general guiding policy at Du Pont, Dress.

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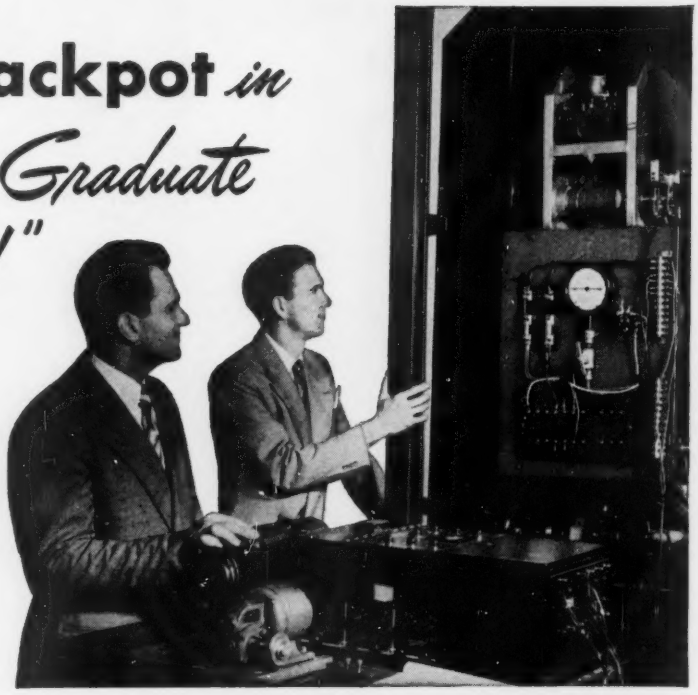

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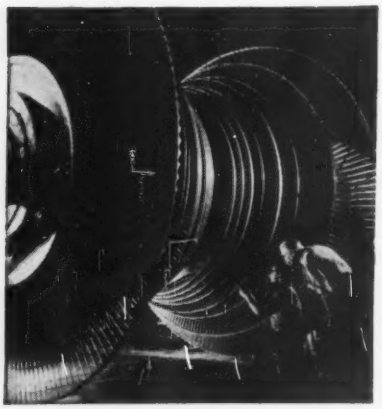

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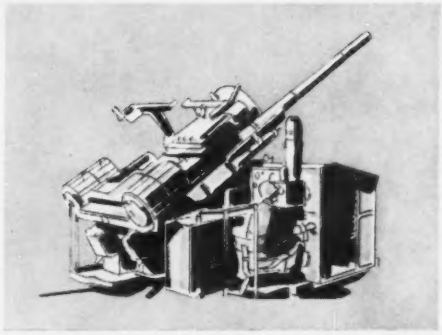

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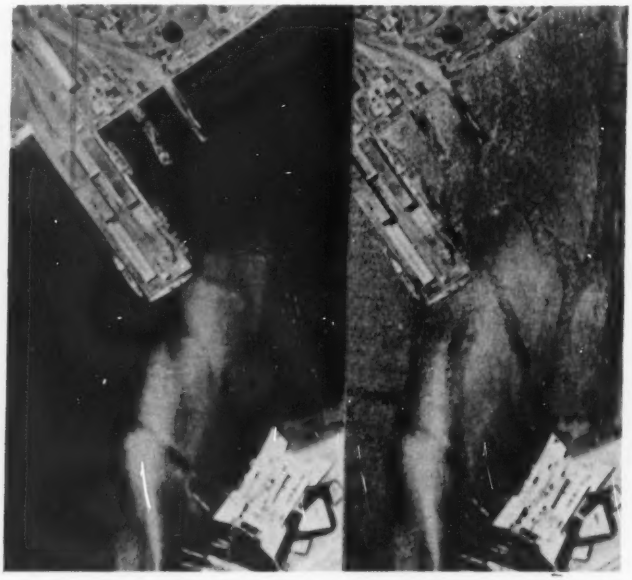
stereo models without a stereograph

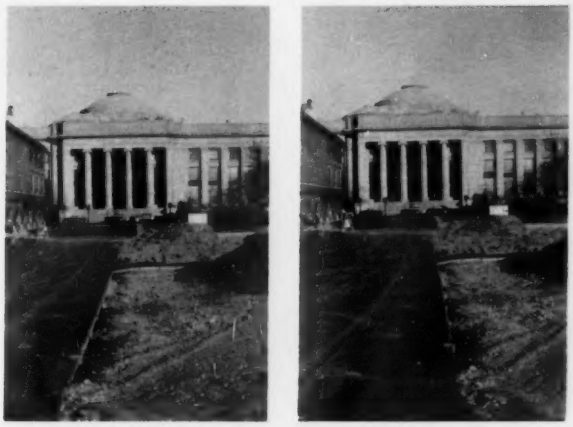
by D. F. Shraeder, '60

Stereo photography has come of age. Early in the century it was merely a fascinating plaything, but now it has progressed to the point where it is used daily in such fields as Cartography, Geology, Engineering, Forestry, Agriculture, City Planning, Archæology, and many others. All of the above fields predominately use air photographs but the method to be discussed is equally applicable to stereo pairs (two overlapping photos which permit stereovision), without any auxiliary equipment, and see a three-dimensional image. If you do not have easy access to aerial photographs, or a stereo-camera, then you may use an ordinary camera to obtain a stereo pair by taking one picture of the desired scene and then moving a few inches to the side and taking another photograph. This method works exceptionally well with models of the female variety.

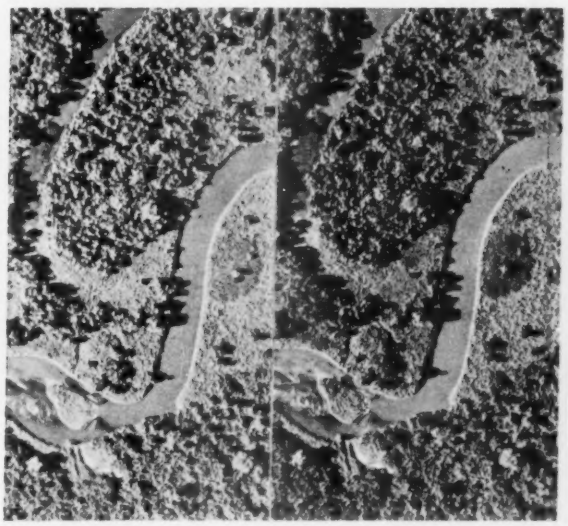
To view any object stereoscopically each eye must receive a slightly different image of the object. The sensations thus produced in the nerves are fused in the brain and are recognized as a three-dimensional, or binocular sensation. To produce this sensation by observing a properly oriented stereo pair requires nothing more than looking at the left photo with the left eye and at the right photo with the right eye. This requires conscious manipulation of the eye muscles, and before the method becomes natural, much concentration and practice. But the results are well worth the effort.

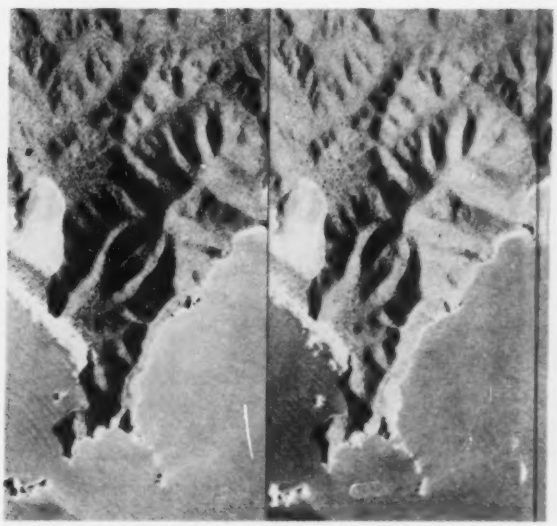
Place two black dots (about one eighth of an inch in diameter) approximately one inch apart on a piece of white paper. Then, holding the paper at normal reading distance, or perhaps closer, focus your eyes on some distant object and without changing focus bring them to rest on the dots. If you are lucky, you won't be, you will see three dots; the center dot being the equivalent of a three-dimensional image. Since you probably will not lock-in, at first, you will see four dots. Concentrate on the two center dots and manipulate your eye muscles until the two dots start moving together and finally fuse. This should be fairly easy with the one-inch spacing and will not take more than a few minutes, but this won't give sufficient coverage to view the photographs reproduced here. Take another piece of white paper and this time space the dots further apart and then practice fusing the two dots together in order to obtain a stereoscopic image. When you can space the dots approximately two and one-half inches apart, and fuse the dots, you will be able to view the photographs stereoscopically.

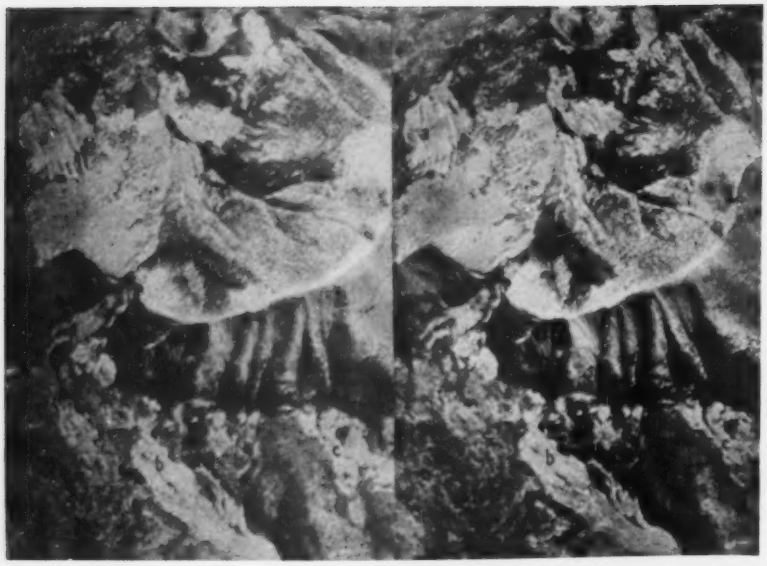


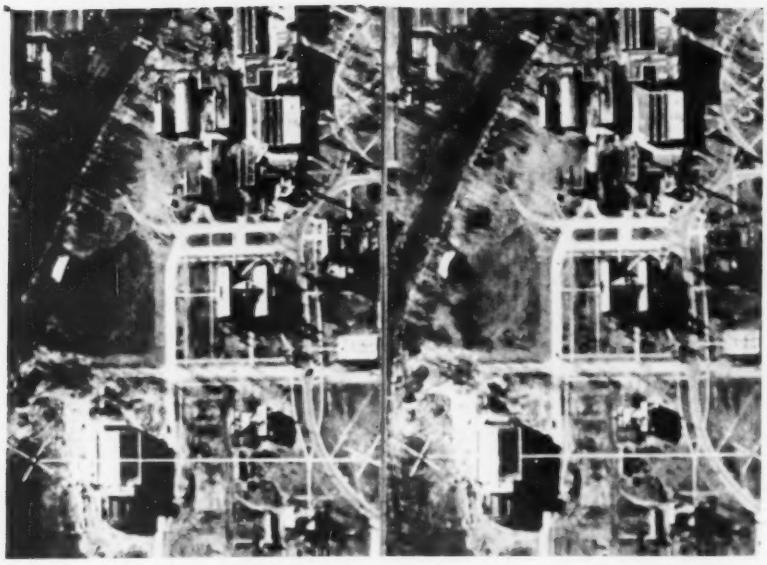


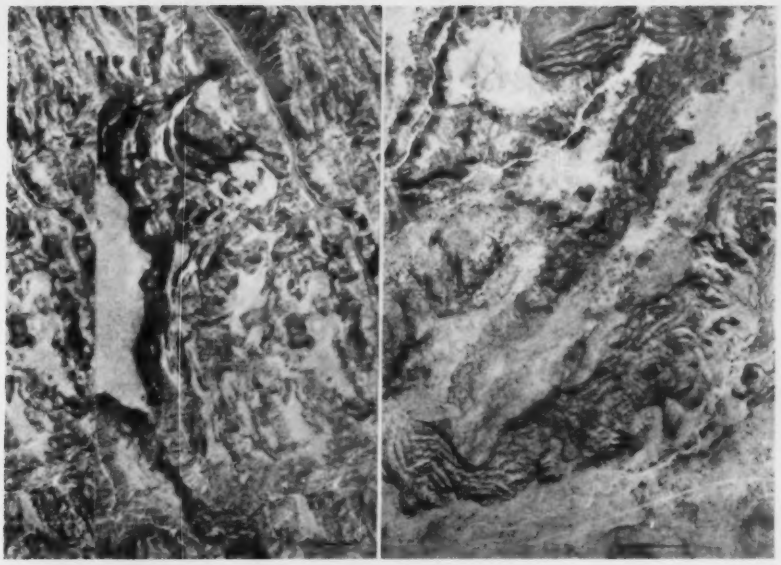
Assuming that you have mastered the above procedure, we will now work on the photographs. On the stereo pair, you have chosen to view, pick out some easily seen section, such as a lake, house, river road, or other prominent part of the photograph and treat these points as you did the dots in the preceding exercises. Once you have your chosen point fused, the rest of the photograph will lock-in and you will be viewing a stereoscopic model. The vertical relief will be exaggerated in the aerial photographs since the photographing stations for each photograph of the stereo pair are approximately one-half mile apart. You can figure out the geometry of the system yourself and if you find you need aid I refer you to Smith's "Aerial Photographs And Their Applications". Many of the uses of the aerial photographs are self-evident but some of them are not as obvious although they are just as interesting. Perhaps it will be of interest to note that most modern maps and charts use the stereoscopic image obtained from vertical aerial photographs to obtain their contours. I now leave you to the photographs and your optometrist.

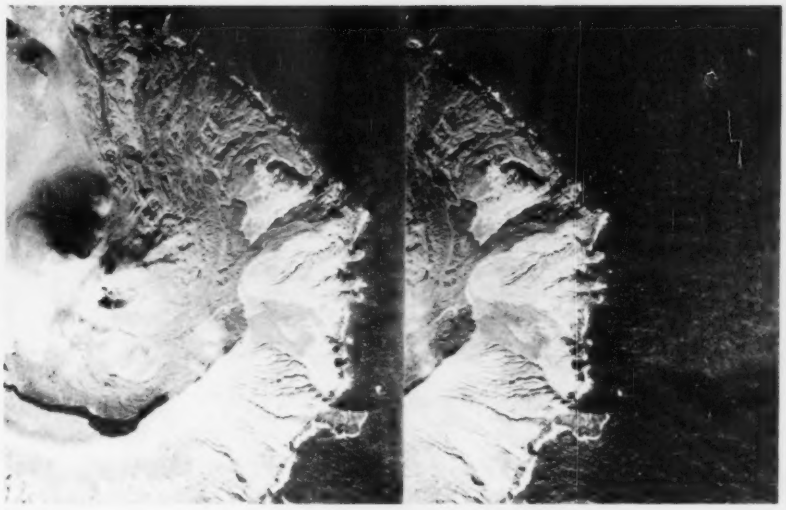


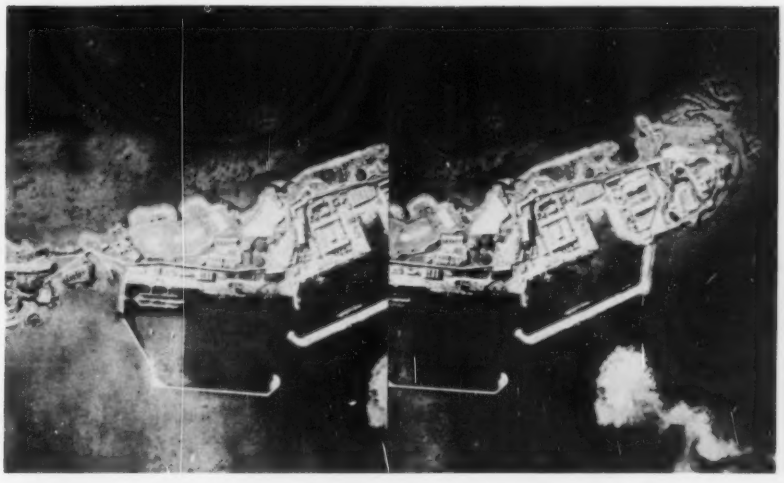












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climatic control and the causes of the ice age

by Hermatilda Klutz, Ph.D.

Many theories have been advanced by geologists, meteorologists, astronomers, and scientists of many other fields to explain the ice ages that present themselves throughout geologic history. The ice ages, though few and comparatively short lasting, have been well scattered through time with what appears to some investigators to be a definite periodicity, although this idea is generally discounted. Glaciations have occurred during the Pleistocene, early Permian and late Carboniferous, early Cambrian and late pre-Cambrian, and several other times during the pre-Cambrian. The earlier pre-Cambrian dates are uncertain but they are provisionally set at 1000 and probably 1500 and possibly 600 or 800 million years ago.

The best known glaciation, of course, is that of the Pleistocene. During the Pleistocene glaciers had four major advances; chronologically they are the Nebraskan, Kansan, Illinoian and Wisconsin. The corresponding European names are respectively the Gunz, Mindel, Riss and Wurm. The American interglacial epochs have been named the Aftonian, Yarmouth and Sangamon in their chronological order while in Europe there are no corresponding names. Paleontologic and geologic evidence indicates that the climates of the Aftonian and Sangamon epochs were warm and wet while the climate of the Yarmouth epoch was dry and cool. Through geologic evidence alone, the four glaciations have been dated, in thousands of years ago, respectively, as 520-490, 430-370, 130-100 and 40-18. This sequence is shown schematically in figure 1.

Any theory which purports to explain the ice ages must have an explanation for the time distribution of the various ages, their various advances and retreats and the vast ages of non-glaciation when warm climates extended far into the polar regions.

The various factors of climatic control that have been proposed as causes or partial causes of the ice ages are listed here:

1. Latitude
2. Moon and Planets
3. Obliquity of the Earth
4. Eccentricity of the Ecliptic
5. Perihelion Phase
6. Content and Composition of the Atmosphere
7. Vulcanism
8. Surface covering
9. Sun Spots
10. Land Elevation
11. Land and water Distribution
12. Atmospheric Circulation
13. Oceanic Circulation
14. Solar Constant

We must now treat each of these factors. A few we can dismiss immediately while others must be examined more thoroughly and then retained as subordinate, if not major, causes of the ice ages.

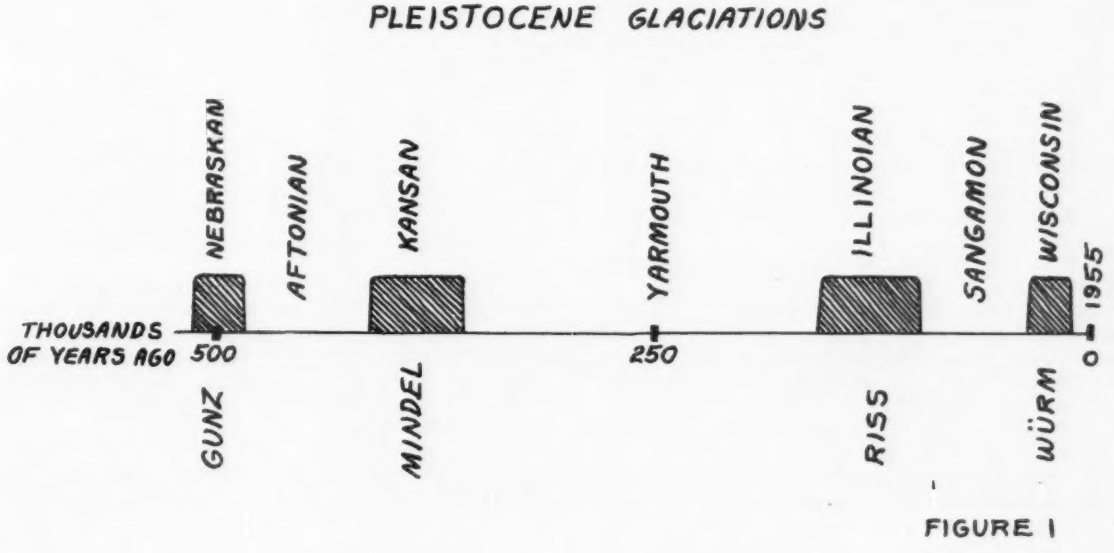
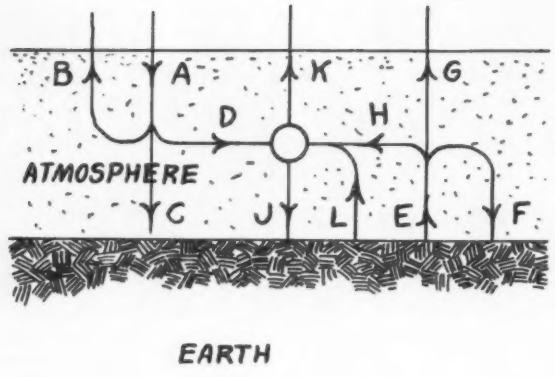


FIGURE 1

FIG. 2



Of course there need not be one single big cause of glaciation. Perhaps it is several accidental combinations of the above factors which bring about the ice ages. Perhaps different ice ages have had different causes or combinations of causes.

Variations in latitude are limited to effects of migrations of the earth's poles or the migration of the earth's lands. Astronomers however, claim that no forces are known which could cause a variation of over 21 degrees (23 miles). Wegener's Theory of Continental Drift, is hardly accepted today on the basis of more thorough investigations of historical geology, and more recently of isotope geology heat measurements. We may, therefore, dismiss this factor.

We may also dismiss the effects due to variations in the apparent brightness of the moon and the planets which by their variations in phase and distance can vary the temperature of the surface of the earth by no more than 10^{-4} degrees Centigrade.

The next three factors have been combined in various ways by various authors as explanations of the ice ages. The variation of the obliquity of the eclipitc is slightly variable. The limits of variation are difficult to calculate. Most astronomers limit this variation, however, to about two degrees.

The eccentricity of the earth's orbit, that is, the distance between the center of the elliptical orbit's center and its focus in terms of the major axis, varies between zero and 0.07 in a period of about 100,000 years.

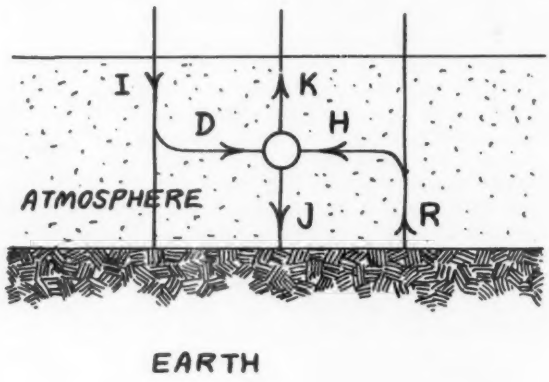
The phase of perihelion (the time of the year when the earth is closest to the sun) which is termed the precession of the equinoxes varies with a period of 21,000 years. That is, since at present the earth is in perihelion during the northern hemisphere's winter, 10,500 years it was in perihelion during the southern hemisphere's winter.

Croll combined the above factors in his theory of the Pleistocene ice age by supposing that in periods of great eccentricity, the hemisphere with its winter in aphelion would have a snowy and cold enough winter to persist through the following summer and bring in an ice age. The heat reaching the earth would be further diminished by solar reflection by the snow and eventually the opposite hemisphere would start icing up by convection. Evidence, however, points out that the ice ages were virtually simultaneous in both hemispheres. Also each ice age would be limited to a fraction of the period of the precession of the equinoxes which is geologically too short a time. Furthermore, such glaciations would have occurred 100 times in the past 3,000,000 years and the end of the Wurm glaciation would be 80,000 years ago instead of the 18,000 years of glacial geologists.

Spitaler reversed Croll's theory and supposed that the hemisphere with its winter in perihelion would have a relatively mild winter, but most of the winter snow would persist through the cool summer. According to his calculations, however, the Wurm glaciation ended 90,000 years ago which again disagrees with the geologic facts.

Koppen and Wegener combined Spitaler's winter in perihelion with the calculated time of greatest obliquity of the plane of the ecliptic to explain the Pleistocene ice ages. Their dates, however, disagree with those determined by geologists.

FIG. 3



Zeuner extended the work of Koppen and Wegener, taking into account such details as reflection due to snow, changes in atmospheric circulation and in oceanic currents. His refined dating has less disagreement with that of geologists than Koppen and Wegener but he finds the Yarmouth Epoch warm rather than cool as geologic evidence shows.

Zeuner's work deserves consideration for it is perhaps an important factor in the climate of the past. Correlation with the geologic past is fair. Again, however, the long absences of glaciation for many years of geologic time is in disagreement with the regularity which should occur through Zeuner's methods.

The temperature at the surface of the earth is determined by the rate of heat flow between space, the atmosphere and the earth itself. In figure 2, the rate of heat reaching the outer limits of the atmosphere, the solar constant of about 720

calories per square centimeter per day is represented by A. B represents that portion of A which is directly reflected back into space; C represents that portion of A which reaches the earth; and D is that portion of A which is absorbed by the atmosphere. E represents the heat leaving the earth by reflection and radiation. F represents that portion of E which is directly reflected back to the earth; G represents that portion of E which is radiated into space; and H is that portion of E which is absorbed by the atmosphere. L represents the transfer of heat between the earth and the atmosphere because of conduction and evaporation. J is the radiation from the atmosphere to the earth and K is the radiation from the atmosphere to outer space. Under conditions of equilibrium we have:

$$A=B+K+G \text{ and}$$
$$E+L=C+F+J$$

The variation of any one of these rates will of course change the nature of the final equilibrium and the consequent temperature of the surface of the earth. For the value of A in calories per square centimeter per day of 720, B has a value of about 320. This reflection can be considered as being caused by dust or by clouds which reflect approximately 75-80% of the sun's light and occupy about half of the sky. Increased cloudiness would have a marked effect not only in the earth's precipitation but in its temperature. The rate of radiation absorption by the atmosphere, D, is small, about 50. We therefore get an influx of heat at the surface of the earth from the sun of about 350 calories per square centimeter per day. The value of F is about 60 and J about 540. Thus the total heat reaching and leaving the surface of the earth is about 950 calories per square centimeter per day, while 720 is the rate at the upper limit of the atmosphere.

We can consider the incoming radiation less the atmospheric reflection, A—B, as I, the effective insolation to the earth and its atmosphere. Also we can let the effective radiation from the earth to its atmosphere and space, R, be equal to E+L—F. Then figure 2 will be modified to figure 3. If a is the coefficient of absorption of the incoming radiation, and b is the coefficient of absorption of the outgoing radiation, we have,

$$D=aI \text{ and } H=bR$$

If we make the assumption that K=J, or that the total amount of radiation absorbed by the atmosphere is re-radiated equally between the earth and outer space we are very close to the truth. Thus we have all energy absorbed by the atmosphere radiated away, half of it to the earth, and the other half to space and the net radiation leaving the earth is equal to the net radiation reaching the earth, or

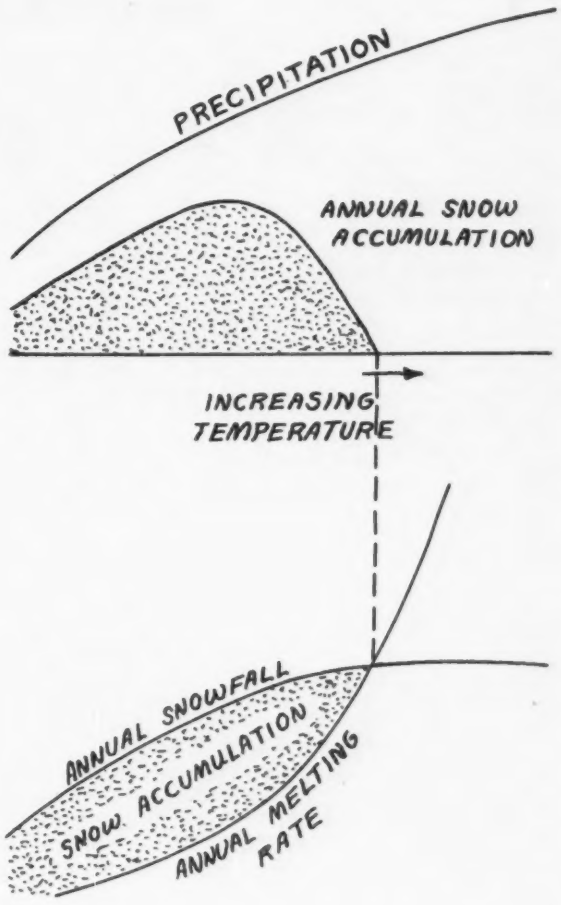
$$R(1-b/2)=I(1-a/2) \text{ or } E=I(2-a)/(2-b)$$

and

$$E \gtrless I \text{ according as } b \gtrless a$$

If the effective insolation is constant, the amount of radiation reaching and leaving the earth's surface, and accordingly its temperature, is increased, equal to, or decreased, accordingly as the coefficient of absorption of terrestrial radiation is greater than, equal to, or less than the coefficient of absorption of solar radiation. This explains the blanketing effect of carbon dioxide, water vapor, and ozone. At the point of maximum intensity, the wavelength of solar radiation is 5000 A and the wavelength of terrestrial radiation is 120000 A, and carbon dioxide, water vapor and ozone absorb more of the smaller wavelength radiation than the longer wavelength, so we have b a and consequently as the percentage of these constituents increase in the atmosphere, the surface temperature increases. For both water vapor and carbon dioxide, for which the degree of absorption of certain wavelengths is exponentially related to the effective thickness of the gas layers, absorption by both gases is nearly 100% (except over cold dry continental regions where water vapor absorption is not so complete) and changes in the concentration of either by as much as 100% will have hardly any effect on the degree of radiation absorption. For radiation from a black body which is the equivalent to the earth, the maximum amount of

FIGURE 4



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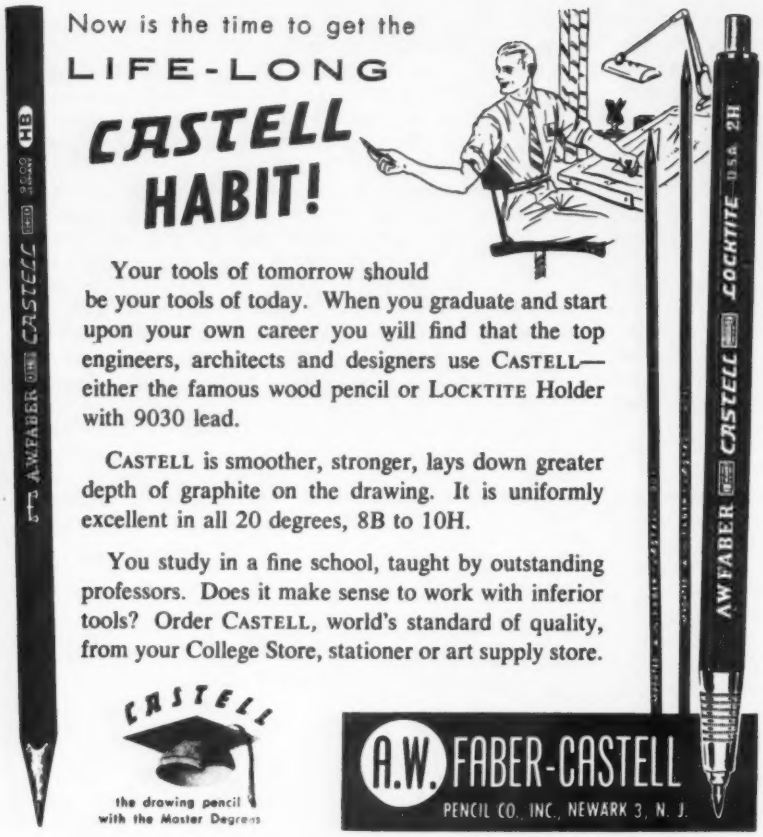

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absorption by carbon dioxide is 14%. Assuming that now the atmosphere absorbs 10% of terrestrial radiation and 1% of solar radiation, the average earth temperature will change by no more than 1.3°C for a doubling or halving of the amount of carbon dioxide. Carbon dioxide will, therefore, play a minor role only, since geologic evidence infers that its concentration in the atmosphere does vary. The variations are, however, long range (as because of the abundance or paucity of plant life for certain geologic periods and can not explain short lived glaciations. The Permian glaciation for instance, has been explained as a result of the exhaustion of the carbon dioxide supply by Carboniferous forests.)

Vulcanism, which for extreme eruptions sends vast amounts of volcanic dust into the atmosphere, is an important factor of climate control. Volcanic dust has just the opposite effect from carbon dioxide, water vapor and ozone. Instead of acting as an agent to keep heat within the greenhouse, it serves to keep it out; that is a b. Pyroheliometric readings following great volcanic eruptions vary by as much as 20% and the climate tends to become cooler following all major eruptions during historic time. 1816, the famous "year without a summer" followed the great eruption of Tomboro and those of Mayon, Soufriere and possibly St. George and Etna. In 1784 Franklin suggested that the then cold winters were caused by contemporaneous volcanic eruptions. Indeed, Asama, Skaptar, Vesuvius and Jokull are known to have erupted around then. Other temperature lows have been correlated with vulcanism and there is no doubt that volcanic action results in appreciable lowering of the surface temperature of the earth.

Following the eruptions of Krakatoa in 1883, Mont Pele and Santa Maria in 1902 and Katmai in 1912, a reddish-brown corona was often observed around the sun, which was from 10° to 12° wide and had an angular radius to the outer edge of from 22° to 23°. The corona was due obviously to the diffraction of the sun's rays. From this corona, it was calculated that the average diameter of these particles is 1.85 microns. Applying a modification of Stoke's viscous fall equation, it was found that it would take fro was found that it would take from two to three years for the dust to come down. Since solar light has its maximum intensity at 0.50 microns and terrestrial radiation at 12 microns, solar light is largely reflected by the dust while terrestrial radiation is scattered by the dust. The ratio of absorption coefficients, a/b, is equal approximately to 30. For a homogeneous shell of dust around the earth the total volume of all the dust would be that of a cube only 179 meters on the side. This quantity of dust for 100,000 years continually being erupted and falling to the earth would produce a layer over the earth of only 0.50 millimeters, too small to be identified in geologic strata. Such a decrease of insolation as 20% that this dust would induce would lower the equilibrium surface temperature of the earth by 10 degrees F. This would be more than enough to initiate and maintain an ice age. It may be noted that much vulcanism preceded the ice ages of the Pleistocene, Permo-Carboniferous and Cambrian-Pre-Cambrian. This factor, however, fails to explain the individual advances and retreats of the Pleistocene. Also there was considerable mountain building which is also considered a climatic factor of some importance. It might be noted here that conditions of high meteor bombardment of our atmosphere or dust from "fallouts" would have similar climatic effects to those of volcanic dust.

The sort of surface covering that would affect the temperature of the surface of the earth is ice and snow. Since over an ice sheet, 80% of the solar radiation is reflected back to space, compared with only 20% in unglaciated regions, the lost solar radiation would have been sufficient to melt 30 feet of ice per year. At the maximum advance of the Pleistocene glaciations, the total area of the earth covered by ice was 13 million square miles, compared with 6 million square miles at present. The 7 million square miles increase represents an increased covering of 3.5% of the earth's surface. Allowing for clouds over the glaciated regions and snow fall and drift ice of the peripheral regions, the resultant decrease of the earth's surface

temperature would be of the order of 5°F. This factor, of course, is only an acceleration factor, and doesn't come into effect until the ice age starts.

Sun spots are related to the climate but the reasons are quite vague. Since 1749 monthly mean sunspot numbers have been recorded. These indices are based on an arbitrary formula, but 0 corresponds to no spots and 100 to 0.2% of the sun's disc covered by spots. Indices have varied between 0 and 206 and show a persistent periodicity of 11.2 years with maxima varying over larger periods of time. Climate follows this sun spot cycle. In the tropical and polar regions the mean temperature is higher by 2°F. during spot minima than during spot maxima. There seems to be no effect in the temperate zones, however. Also during sunspot maxima there are 20% more thunderstorms throughout the world than during sunspot minima. This 11.2 year cycle has even been observed in glacial days of the late Carboniferous of Australia. Humphreys attempted to explain the increase in earth temperature with sun spot minima by suggesting that during minima more ultraviolet radiation is included in the sun's spectrum. This radiation if it has a wavelength of less than 1850 A is strongly absorbed by the oxygen of the earth's atmosphere, and the oxygen is converted into ozone. The ozone has the same effect on the earth's temperature as do carbon dioxide and water vapor. Observations, however, indicate that ultraviolet radiation is higher during spot maxima. At any rate, although the causes of the relationship between climate and sunspots is unknown, the relationship is known, and sunspots are definitely climatic control factors, although not necessarily the kind to cause an ice age by themselves.

The next four factors should be treated together: land elevation and distribution of land and water, atmospheric and oceanic circulation. All of these factors are intimately related with orogenic movements. Brooks has plotted the major orogenic (mountain building) epochs and the ice ages versus time and a remarkable correspondence seems apparent. According to his plot, glaciations follow mountain building periods by a few million years. Two reasons for the delays between the apeces of orogeny and glaciations are given. One is that it takes time to cool the oceans which act as great climate tempering masses, and the other is that the maximum mountain altitudes are not attained until erosion has worked over the elevated areas, lightened the supported load and allowing it to be elevated even more.

The most obvious effect of land elevation is the general reduction of surface temperature with altitude of 3 degrees Fahrenheit per 1000 feet of elevation. This, along with the increased precipitation due to adiabatic cooling of wet air masses forced up mountain sides, explains glaciation in the mountains, but there are other factors which explain the general decrease throughout the earth in the surface temperature. These include the increased radiation to outer space by high ground over lower ground, the reflection of solar radiation from the surface of clouds formed about mountain ranges, the cooling power of the mountain glaciers reflection of sun light, and the cooling due to increased evaporation which in turn had to match the increased precipitation. It has been estimated or guessed the effects of these factors to be, respectively, negligible, one, three and four degree Fahrenheit decreases in the mean world temperatures. Altogether this accounts for eight Fahrenheit degrees which is quite enough for glaciation.

An increase in land area or continentality brings about an increase in the extent and degree of continental climate. Climates tempered by the ocean are more moderate than the extreme hot and cold climates of inland continental areas. Consequently during a period of much land surface area exposition, as following orogenic movements, climates of the earth are generally more extreme and glaciers can be aided in their growth in certain extreme regions.

Orogeny also affects oceanic currents which are very important climate controls. Such simple openings or closings of straits as between Iceland and Scotland, Greenland and Labrador, Asia and

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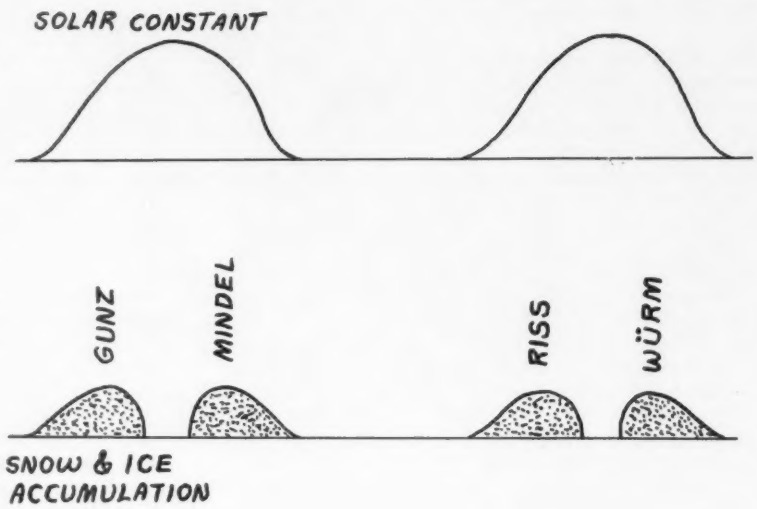
Alaska and many other locations would bring about radical changes in the climates of certain locations of the earth. Of course such valves as these are opened and closed quite a bit during times of mountain building.

Atmospheric circulation is a function of land and water distribution, oceanic currents and land elevations, all of which are affected by orogenic movements. Naturally, changes in this factor will bring about changes in climate.

The four above factors put together adequately explain the ice ages in general, and observations agree with the theory for the correlation of orogeny with glaciations, but they fail to explain the history of the Pleistocene glaciations in particular, nor give an adequate basis for several advances and retreats.

FIGURE 5



Variations in the solar constant were dismissed by early investigators but more recently it has been given considerable attention. Its biggest boost was given by Sir George Simpson who proposed the idea that the ice ages were due to an increase in the solar constant, and a consequent increase in insolation and average surface temperature of the earth. His theory accounts remarkably well for the Pleistocene glacial and inter-glacial epochs. His theory goes as follows: increased solar constant causes increased insolation causes increased world mean annual temperature. This also causes increased temperature contrast between warm and cold zones of the earth which in turn results in more active convection of atmosphere currents, increased evaporation, cloudiness and precipitation. With increased precipitation comes increased snowfall and therefore a growth of glaciers. Eventually, however, the increased insolation supplies enough heat to the earth to melt the winter accumulations of snow and more precipitation falls as rain and glaciers retreat. The variation of these different climate parameters with temperature are given in figure 4. Two complete cycles of solar radiation would explain four advances and retreats of glaciers as in the Pleistocene. See fig. 5. In fact it explains excellently the climates of the interglacial epochs, warm and wet during the Aftonian and Sangamon, and cold and dry during the Yarmouth. Also the short in duration interglacial Aftonian and Sangamon and the longer Yarmouth epoch are explained.

Astronomers have sought to solve the problem of what could make the output of the sun's energy change. Various answers have been suggested including turbulent readjustment of the hydrogen in the sun's core, and even nova, but the one outstanding reason for variation in solar radiation was given by Hoyle and Littleton of Cambridge. According to them, increased solar radiation might very well be caused by the encounter between the sun and interstellar hydrogen. Clouds of observed hydrogen are estimated to occupy 5% of interstellar space, having densities of 10^{-22} gm/cm^3 and possibly even larger. They are extremely irregular and their largest dimensions are of the order of 10^{19} cm. In our galaxy these clouds and the sun are rotating about the center with velocity variations of the order of v=10 km/sec. Should our sun pass through such a cloud at 10 km/sec its luminosity would increase, but the increase could be even greater the slower the speed of encounter. For v=2 km/sec which has an appreciable probability of occurring, it would take 2 million years to travel 10^{19} centimeters.

For a moderate velocity matter far beyond Pluto will fall into the sun, attaining a velocity of the order of the sun's escape velocity of over 600 km/sec. and upon impact will be converted into thermal and radiant energy. For d=10^{-21} gm./cm^3 and v=1 km./sec. the equilibrium increase in the amount of solar radiation is 10%. For the same density, the total amount of hydrogen per square centimeter along a line of sight from the earth to the sun would be of the order of 10^{-7} grams which is an undetectable quantity.

The two required cycles of solar radiation required by Simpson's theory could be explained by the sun passing through two arms of the same cloud or even different clouds. The long periods of geologic time without glaciations is easily explained because the sun didn't intercept interstellar hydrogen clouds.

Of all of the theories presented, the Simpson-Hoyle-Littleton combination agrees best with geologic evidence. Less in agreement, but important nevertheless are theories of astronomical coincidence and vulcanism and orogeny. Still a combination of factors may be responsible and different ice ages may have had different causes. One thing, however, is sure: If we ever get all of the factors mentioned above working together in the same dircction, this earth will have one BIG glaciation.

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special theory of relativity

by Neil MacFarlane, '58

Figure 1 shows a man riding a bicycle on top of a flat car. The flatcar is moving forward with a velocity of 50 mph with respect to the ground. The man in turn is riding his bicycle at a velocity of 5 mph with respect to the top of the flatcar.

Question: How fast is he going with respect to the ground? If you said anything but 55 mph, somebody might think you're crazy, but as it turns out, as you may have expected by now, 50 mph plus 5 mph does not add up to 55 mph. However as has been the case before, when we have such small velocities as 50 and 5 as compared with the speed of light, the relativistic answer is so close to the classical answer, that the difference is immeasurable. Let us call the flatcar the S′ system, moving with velocity v with respect to the ground, which we can call the S system. The bicycle rider is traveling at a velocity u with respect to the S′ system. (Fig. 2.)

Since velocity is defined as displacement per unit time,

$$u = \frac{x'}{t'}$$

but from the Lorentz Transformation, we get

$$x = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Dividing these equations, we have

$$\frac{x'}{t'} = u = \frac{\frac{x - vt}{\sqrt{1 - v^2/c^2}}}{\frac{t - vx}{\sqrt{1 - v^2/c^2}}} = \frac{x - vt}{t - \frac{vx}{c^2}}$$

The bicycle rider's velocity with respect to the ground, or S system, will be x/t by definition of velocity. Let us call x/t, which is the sum of u and v, V_s.

$$u = \frac{x}{t} = \frac{vt}{t - \frac{v^2 t}{c^2}}$$

Dividing numerator and denominator of the above equation by t, we get

$$u = \frac{\frac{x}{t} - v}{1 - \frac{v}{c^2}\frac{x}{t}} = \frac{V_s - v}{1 - \frac{vV_s}{c^2}}$$

Solving for V_s,

$$u = \frac{uvV_s}{c^2} = V_s - v$$

$$uc^2 - uvV_s = V_s c^2 - c^2 v$$

factoring and dividing, $V_s = \frac{c^2(u+v)}{c^2 + uv}$ $\qquad V_s = \frac{u+v}{1 + \frac{uv}{c^2}}$

This equation is known as the addition of velocities theorem. From it, we see that for all practical purposes,

$$\frac{c^2}{uv} = 0.$$

When this is the case, the equation of classical physics, $V_s = u + v$ which again illustrates why classical physics has been so successful, even though it is wrong.

Let us take a striking example to show the true nature of the addition of velocities theorem. Suppose u=½ the speed of light and v=¾ the speed of light. The sum of these velocities would be by classical physics 1¼ times the speed of light. But by relativistic physics,

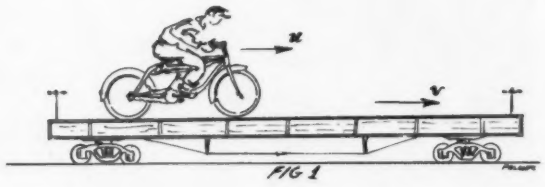

FIG 1

$$V_s = \frac{\frac{1}{2}c + \frac{3}{4}c}{1 + \frac{3}{8}\frac{c^2}{c^2}} = \frac{5c}{\frac{11}{8}} = \frac{40}{11}c$$

We see that ½c and ¾c add up to 10/11 c which is still less than c!

Here again, we see the speed of light in a limiting role. Try substituting some values for u and v in the addition of velocities equation and see that it is impossible to get V_s to come out greater than c, even when values of u and v greater than c are substituted. The graph of

$$V_s = \frac{u + v}{1 - \frac{uv}{c^2}}$$

plotting negative velocities as well as positive ones, looks roughly as shown in fig. 3.

Notice that the curve is defined and continuous for all values of the variable, but at no point does it become greater than c (or less than —c for negative velocities).

* * * *

Part VI Relativistic Mass and $E=mc^2$

Perhaps the most striking part of relativistic physics is the part that shatters all we ever learned in high school physics about mass, namely that a body's mass is not constant, but varies with its velocity.

In order to find a relation between mass and velocity, we will have to make use of the law of conservation of momentum (which we will have to assume is true).

Figure 4 shows an observer in the S′ system who has taken two balls whose masses m′ are equal in the S′ system. He has set them in motion with equal and opposite velocities so that they are about to collide. It was mentioned in the introduction that one of the disadvantages of limiting ourselves to lower mathematics is that the algebra involved will become quite messy. This is a complete understatement for what ordinarily would be about to follow. Eight full pages of nothing but algebraic junk are required before we arrive at the answer we're looking for. So in order to circumvent all this algebraic exercise, we are going to "set up" the problem so that the answer comes out nice and easy. To do this we simply fix it so

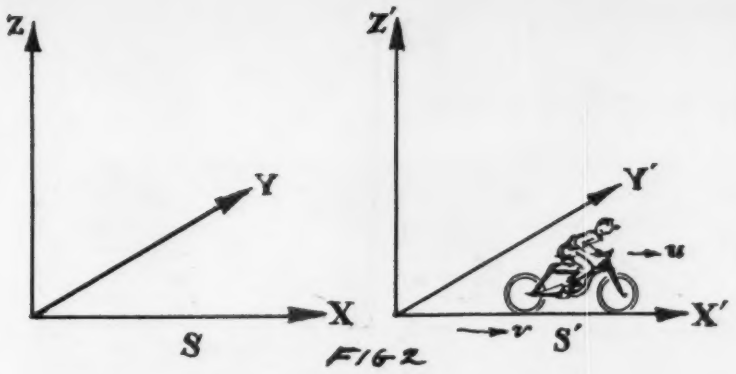

FIG 2

that ball number 2 happens to be at rest in the S system. In other words, we will make its velocity with respect to the S′ system equal to —v. If ball number one has a velocity equal and opposite to that of ball 2, then ball one's velocity must be v. Thus we see that we have only v's to worry about, and not four or five different velocities that we would have got if we had set up the problem in a completely general way. Since all we want to do is to find out how mass varies with velocity, we see that we can still give the balls any velocity we want (except faster than light of course), and so therefore we won't be invalidating the proof in any way by taking such a special case.

Referring back now to figure 4, balls one and two have an equal mass m′ when measured by the observer in the S′ system. Also their velocities when measured in the S′ system are v and —v respectively. But to the observer in the S system, ball 1 seems to have a mass of m_1 and ball 2 seems to have a mass of m_2. (Notice that we are not assuming $m_1=m_2$ just because the two balls have equal masses in the S′ system. Nor are we assuming that $m_1=m'$ or anything like that even if they are the same ball.) Now the balls have a perfectly inelastic collision so that they fuse together forming a mass of 2m′ in the S′ system or a mass of m_1+m_2 in the S system. Since the balls' velocities in the S′ system were equal and opposite, they are now at rest in the S′ system, but they are therefore moving with a velocity v in the S system. Therefore, the observer in the S system would write the law of conservation of momentum as

$$(m_1+m_2)v=m_1u_1+m_2u_2 \qquad (a)$$

The term on the left is the momentum after the collision and the term on the right is the momentum before the collision, where u_1 is the relativistic sum of v and v, and u_2 is the relativistic sum of v and —v. By the addition of velocities theorem,

(b)

$$u_1=\frac{v+v}{1+\frac{v\cdot v}{c^2}}=\frac{2v}{1+\frac{v^2}{c^2}}$$

and

$$u_2=0$$

Substituting $u_2=0$ into equation (a) and rearranging terms, we get

$$(m_1+m_2)v=m_1u_1+m_2(0)$$
$$(m_1+m_2)v=m_1u_1$$
$$m_1v+m_2v=m_1u_1$$
$$\text{or} \quad m_1(u_1-v)=m_2v \qquad (c)$$

When we look at equation (c), we must ask ourselves whether we want to get rid of v in terms of u_1 or get rid of u_1 in terms of v. (Hereafter we may as well drop the subscript on the u, since we no longer have a u_2.) We see that we are not the least bit interested in v, because u is the velocity with which the mass m_1 is moving with respect to the S system. We have arranged for m_2 to be at rest in the S system, so that m_2 will represent rest mass in the S system, and then m_1 will represent the same mass, but moving with a velocity of u, not v, with respect to m_2. The resulting equation relating m_1 and m_2 will therefore be the expression that we are looking for, since it will be relating rest mass with moving mass.

Therefore, we must solve equation (b) for v and substitute it into equation (c).

From equation (b), $u=\frac{2v}{1+\frac{v^2}{c^2}}$

$$uc^2+uv^2=2vc^2$$
$$uv^2-2vc^2+uc^2=0$$

Solving for v by the quadratic formula,

$$v=\frac{2c^2\pm\sqrt{4c^4-4u^2c^2}}{2u} \qquad v=\frac{c^2\pm c\sqrt{c^2-u^2}}{u}$$

Both $v=\frac{c^2-c\sqrt{c^2-u^2}}{u}$ and $v=\frac{c^2-c\sqrt{c^2-u^2}}{u}$ check when substituted back into equation (b). We have, therefore, no idea which value of v will work when substituted into equation (c). We do know, however, that when u=0, $m_1=m_2$, because we originally chose balls of equal mass when they were at rest relative to each other. Therefore we will have to solve equation (c) twice—once using $v=\frac{c^2-c\sqrt{c^2-u^2}}{u}$ and once using $v=\frac{c^2-c\sqrt{c^2-u^2}}{u}$ and then see wnich solution gives $m_1=m_2$ when u=0.

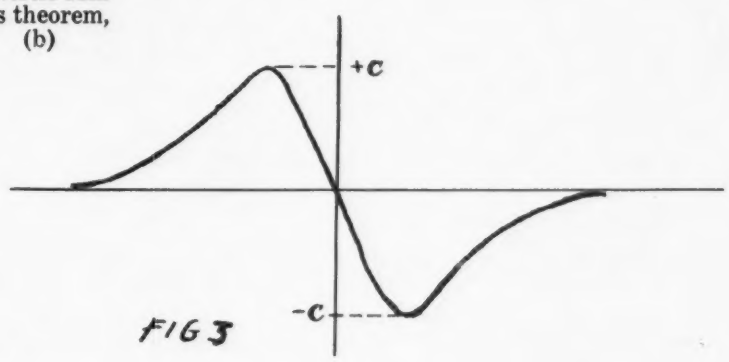

FIG 3

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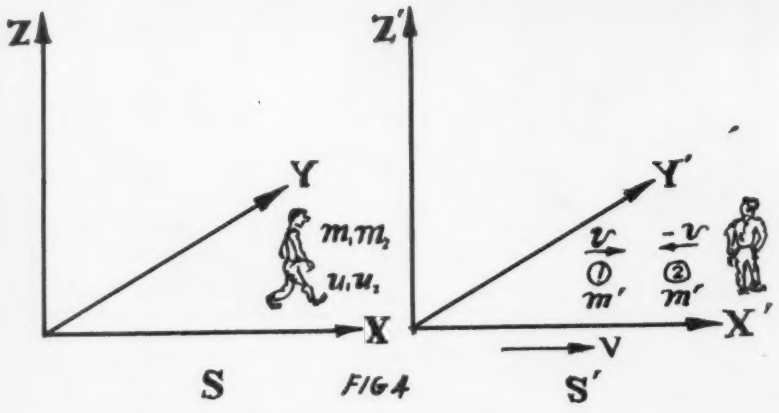


FIG 4

Substitution of the first value above gives a meaningless answer. Substituting the second yields

$$m_1(u-v)=m_2v \qquad (c)$$

Substituting, we have

$$m_1\sqrt{1-\frac{u^2}{c^2}} = m_2$$

This makes sense, since when $u=0$, $m_1=m_2$. Now solving for the mass of the moving ball, we get

$$m_1 = \frac{m_2}{\sqrt{1-\frac{u^2}{c^2}}}$$

Using the conventional symbols m_0 for rest mass (m_2) and m for mass when moving at a velocity v, we get the familiar expression for relativistic mass,

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

Notice that this equation is the same form as that for relativistic time, and that as v approaches c, m becomes infinite. Here lies the best argument that the speed of light can never be reached or surpassed by a material object, because an infinite mass would require an infinite force to move it, and since no such force exists, speed equal to or beyond that of light is not possible.

This formula has been verified experimentally; the mass of an accelerating electron has been found to increase in exact accordance with this equation.

Note the interesting fact that $m=\frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ can be written

$$m = m_0\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

which when expanded by the binominal theorem yields

$$m = m_0\left(1+\tfrac{1}{2}\frac{v^2}{c^2}+\cdots\right)$$

the rest of the terms of the expansion being negligible, thus

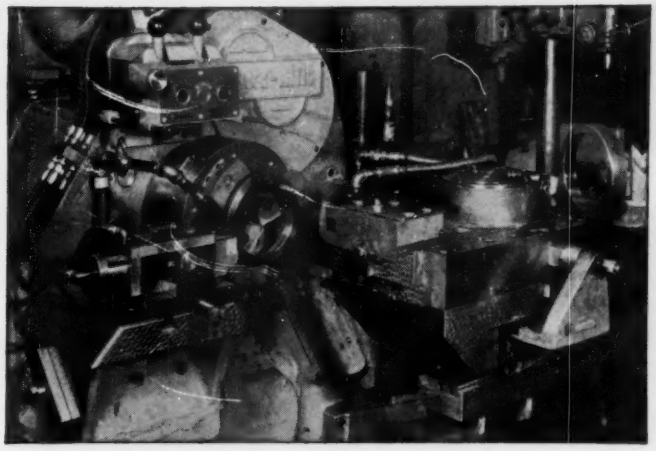
$$m = m_0 + \frac{\frac{1}{2}m_0v^2}{c^2}$$

but notice that $\frac{1}{2}m_0v^2$ is the expression for kinetic energy, E. hence

$$m = m_0 + \frac{E}{c^2}$$

or $\frac{E}{c^2} = m - m_0$ which is the increase M in the mass due to its velocity. So, $E=Mc^2$

Another page for **YOUR BEARING NOTEBOOK**



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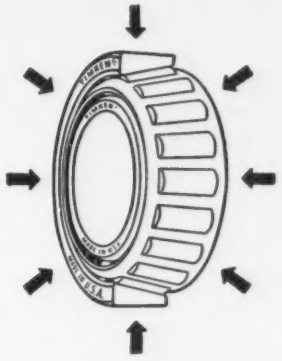

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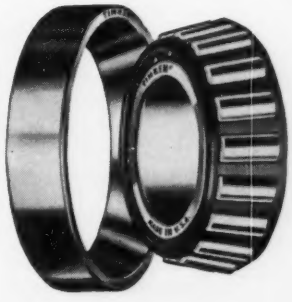

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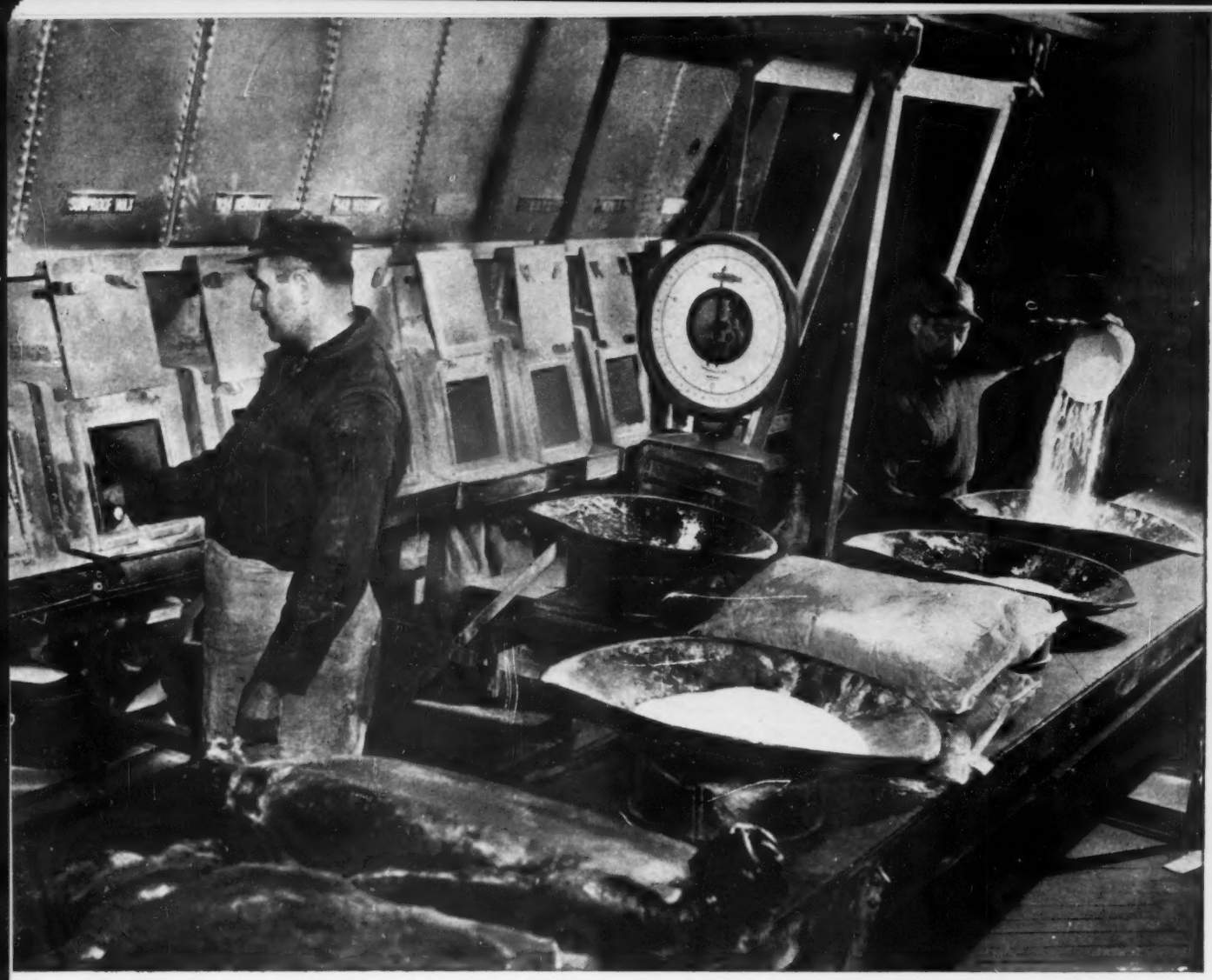

Preparation of Rubber Insulation and Jacket Compounds

MATERIALS AND THEIR PREPARATION. The materials used in the preparation of rubber insulation and jacket compounds may consist of natural or synthetic rubber along with mineral rubber and reclaimed rubber and the necessary compounding ingredients consisting of anti-oxidants, fillers, pigments, plasticizers and vulcanizing agents. The rubber or rubber-like materials are given a preliminary mastication or break-down on rubber mills or internal mixers to facilitate subsequent compounding operations. They are stored in a suitable form until required for compounding.

The required compounding ingredients, except the vulcanizing agents, used in insulating compounds, are carefully weighed into a suitable container. The plasticized rubber or rubber-like materials are weighed last. The vulcanizing agents are weighed in a separate container.

COMPOUND MIXING. Rubber insulation and jacket compounds may be mixed on rubber mills or in internal mixers.

The rubber mill consists of two driven rolls about 28 inches in diameter and from 60 to 84 inches in length. The axes of the rolls are held in a single horizontal plane by the mill frame above a suitable pan. Adjustments are provided to control the spacing between the rolls. Each roll is equipped—for water circulation—for cooling. The rolls rotate in opposite directions in such a manner that the surfaces approach each other at the top. The surface speed of the back roll is about 1.2 times that of the front roll. This difference in surface speed assists greatly in break-down of the rubber and incorporation of the compounding materials.

The rubber-like materials, and mineral rubber, when used, are placed between the rolls first and masticated until so plasticized that they form a continuous sheet on the front roll. The solid ingredients, except the vulcanizing agents for insulating compounds, are then placed on the mill and incorporated in the rubbers. Any solids which drop between the rolls are retained in the mill pan and then returned to the mill.

After the solid materials have been incorporated, the batch is thoroughly blended by cutting the rubber sheet about half way

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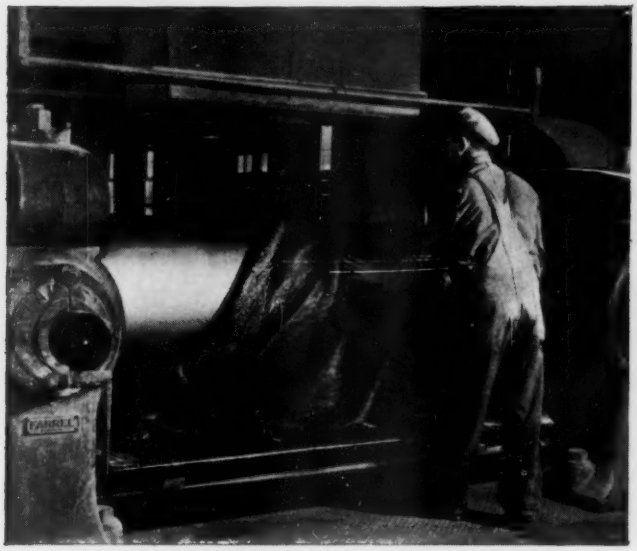
across the roll from alternate ends and folding it back over the uncut portion. This blending may require about fifteen minutes and the entire mixing cycle approximately a half hour. After blending, the compound is removed from the mill in rolls suitable for feeding to the strainer.

The internal mixing unit consists of a mixer located above a rubber mill. The mixer consists of essentially two rotors with spiraled blades rotating in opposite directions at different speeds in a closed chamber. The direction of the spiral of the blades changes at the middle of the rolls. An air-controlled ram forces the materials into the mixing chamber. The mixed batch is discharged from the bottom through a hydraulically operated gate.

The effectiveness of the internal mixer as compared with the mill for breaking down and compounding rubber is evident from a consideration of its method of operation. In addition to the difference in the rate of rotation of the rotors, the interrupted spiral of the blades produces a continuous and uniform movement of the compound

Compound mixing



from the middle to the ends of the rotors. The walls of the chamber are stationary and hence the difference in rate of movement of material adjacent to the rotors and the walls is great. These conditions insure that every part of the batch being mixed will come in contact with every other part in a relatively short time. Mixing requires about fifteen minutes. After mixing, the compound is discharged to the mill below from which it is removed in a form suitable for feeding to the strainer.

STRAINING. The strainer consists essentially of a mechanically driven screw located in a cylindrical cast iron housing. The housing is provided with an opening for feeding the screw and supports the head of the strainer. The head at the outlet end of the screw provides a suitable support for a thirty-six mesh screen through which the rubber insulating compounds are forced by the screw. The strainer operates on the same general principle as the ordinary household food chopper.

The mixed compound is fed into the strainer and forced through the screen. Large particles of foreign or undispersed materials are retained on the screen. The strained rubber compound is returned to a mixing mill or internal mixer where the vulcanizing agents are added. The complete insulating compound is then removed from the mill in sheets for immediate application to wire or for storage.

Jacket compounds are prepared in the same general way as insulating compounds except that the vulcanizing agents are incorporated along with the other solid fillers in mill mixing or on the sheeting mill of the internal mixing unit. Jacket compounds are not strained.

LATEX COMPOUNDING. Compounding rubber in the form of latex involves the handling of rubber in the form of a liquid and, therefore, requires lighter and less costly equipment than that just described for the compounding of plastic rubber. In addition to the actual preparation of the compound, it involves, for latex insulation, the purification of the rubber in latex form.

Latex rubber is purified by diluting a known quantity of latex to approximately 33 per cent solids and heating to a temperature of 150°F. in a steel tank provided with a stirrer. The required amount of creaming agent, dissolved in water, is then added and the mixture stirred. The stirring is discontinued and the warm latex allowed to stand for about 48 hours. The rubber, being lighter than water, rises to the top in much the same way that cream separates from milk. The bottom layer, the serum containing the major portion of the impurities, is discarded leaving the purified rubber in the form of a cream in the tank. This process is repeated until rubber of the desired purity is obtained.

For use in latex compounds, ordinary rubber compounding ingredients are ground more finely, thoroughly protected, and wet with water. This is accomplished in a ball mill. A ball mill consists of a porcelain lined steel drum, provided with a suitable opening and supported with its axis horizontal in such a manner that it can be rotated. The cylinder is about half-filled with flint pebbles.

Definite amounts of the various compounding ingredients, together with the required amounts of protective agents and water, are then placed in the ball mill and suitably ground. Sulfur, being the most difficult material to grind, wet and protect, is milled for about three weeks. All the other ingredients require about one week.

The required amounts of these properly protected and wet ingredients are then carefully weighed and added, along with the stabilizers and water, to a known amount of purified rubber, in the form of latex. The mixture is stirred for about two hours to insure thorough mixing. It is then transferred through a 100 mesh strainer to a storage tank until applied to wire.

Latex compounding

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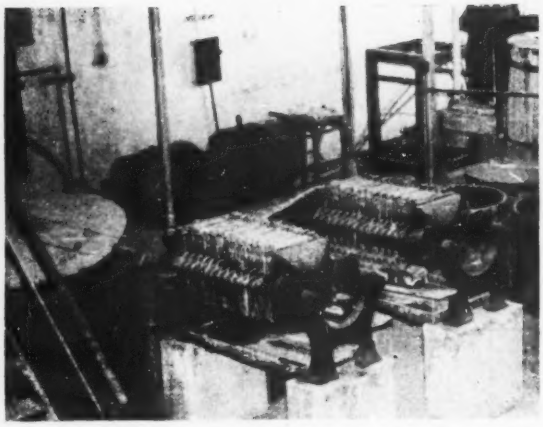
electrolysis and associated studies

by Kenneth Mitzner



BANK OF CELLS in Lobeth pilot plant electrolyzes aluminum sulfate to Al(OH)

I. *Development of Laws and Theories of Electrolysis and Ionization*

Electrolytic conductors, or electrolytes, are materials which conduct an electric current through an actual transfer of matter; this transfer is shown by changes in concentration and frequently by visible separation of material at eiquently by visible searation of material at either pole of the conductor. Electrolytes may be subdivided into two classes: substances which conduct electrolytically in the pure state, such as fused salts and solid halides of certain metals, and substances which conduct electrolytically only in solution. Most common electrolytic solutions use water as a solvent; however, liquid ammonia is also in fairly common use among scientists, and complicated electrolytic systems using such solvents as metallic hydrides and hydrozine (N_2H_4) have been developed. Primarily, electrochemistry is concerned with the behavior of electrolytic solutions in water.

Attempts to discover the mechanism of electrolytic conduction date back to the obsolete Grotthus theory of 1806, but no concrete progress was made until 1833. In this year, Farady developed the theory that an electrolyte consists of negatively-charged particles (anions) moving toward the positive pole (anode) and positively-charged particles (cations) moving toward the negative pole (cathode).

At about the same time, Farady also announced the laws of electrolysis, which are as follows:

(1) The mass of any substance liberated at an electrode during electrolysis is proportional to the quantity of electricity passed through the cell.

(2) When the same quantity of electricity is passed through different electrolytes, the masses of the substances liberated at the electrodes are proportional to their chemical equivalend weights, i. e., the weights of a substance which will combine with or replace one gram of hydrogen.

Faraday's laws hold for dissolved, fused, and even solid electrolytes, as long as all conduction is of an electrolytic nature. Changes of state, temperature, concentration, or other conditions have no effect on the validity of the laws. Quantitatively, Faraday's laws be expressed as

$$w=ce$$

where w is the weight of the substance deposited or, if one electrode is attacked during the reaction, dissolved; c is the number of coulombs which have passed through the circuit; and e is the electrochemical equivalent of the substance (1/96,500).

In 1853, Hittorf began experiments to discover what part of the current was carried by the anions and what part by the cations. Electrolytic current, unlike electronic current, consists of particles of opposite polarity moving in opposite directions; consequently, it is the sum of the two currents. As different ions have different mobilities (or velocities), the positive current may be greater than the negative current or vice versa. At first it may seem that in such a case there will be more of one kind of ion discharged and the solution will lose its chemical equilibrium. However, examination shows that this is not the case. Assume that the ionic velocities of the cations and anions in a solution are in a ratio of two to three. As each cation arrives at the cathode it takes on an electron; one of the many anions which are concentrated around the anode is discharged to make this electron available. As each anion arrives at the anode, it surrenders an electron which passes through the external circuit by displacement and discharges one of the cations clustered around the cathode. Thus five anions and five cations are discharged. The cations carry 2/5 of the total current and the anions, 3/5. If we designate the cation mobility as u and the anion mobility as v, we derive the following formula for the fraction of the current carried by each type of ion:

$$t_c = \frac{u}{u+v} \qquad t_a = \frac{v}{u+v}$$

t_c and t_a, the fractions are known as the transport numbers of the respective ions.

Hittorf's experiments, based on the change in concentration in the anode and cathode compartments of a special cell, showed that the transport number varies with the type of ion, the temperature, and the concentration. Later investigators have made corrections in the Hittorf transport numbers to allow for the mechanical or chemical transportation of water from one compartment to another, which throws Hittorf's concentration data off a little bit.

Arrhemius' theory of ionization, proposed in 1883, is the accepted one today. It states that molecules of electrolytes in solution dissociate to form ions carrying positive and negative charges, so that the number of positive charges equals the number of negative charges. These ions have different properties than the element, properties which are characteristic of the ion in any compound. Radicals do not break up, but a substance may ionize in more than one way and form different radicals. Ions are free to move throughout the solution and under the influence of an electric current are directed toward the electrode of opposite sign. Not all the molecules, but rather a considerable portion were assumed by Arrhemius to ionize. He considered the degree of dissociation to be a function of the concentration of the electrolyte, approaching 100% in dilute solution. As shall be seen, other factors than concentration affect the apparent and actual degree of dissociation, and some substances are ionized 100% even in concentrated solutions.

Van't Hoff in 1887 showed that the gas law equation with osmotic pressure substituted for gas pressure was applicable to dilute solution of non-electrolytes but not to solutions of electrolytes. To compensate for this discrepancy, Van't Hoff added another factor to the law. The Van't Hoff factor is the ratio between the number of actual particles of solute present in a solution and the number of molecules of solute present. For example, potassium hydroxide (KOH) ionizes completely to form K and OH , therefore the Van't Hoff factor for a solution of KOH is two, for there are two times as many particles as molecules. In the case of such strong electrolytes as KOH, Van't Hoff disproved Arrhemius' theory. Given the fraction of molecules which dissociates ( ) when each dissociated molecule forms ions, the Van't Hoff factor (i) may be found by the equation:

$$i = 1 - \alpha + \nu\alpha$$

As the Van't Hoff factor can be found by boiling or freezing point or osmotic pressure measurements, the formula is usually used to find the degree of dissociation in the form:

$$\alpha = \frac{i-1}{\nu-1}$$

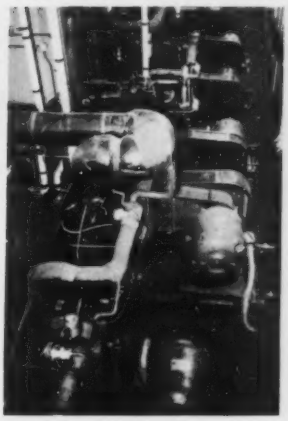
as found by Van't Hoff, agreed for weak electrolytes with as found by Arrhemius' equation

$$\alpha = \frac{\Lambda c}{\Lambda_o}$$

where is the *equivalent conductors*—that is the conductance of that volume of the solution which contains one equivalent weight of the solute when that volume is in the form of a cylinder one centimeter in length with the electrodes as bases —of the solution at the given concentration and is the limiting value of the equivalent conductance for the given electrolyte. Van't Hoff's and Arrhemius' formulas are still accurate enough for all but the most exact calculation where weak electrolytes are involved.

Van't Hoff's work, other experiments, and the discovery by means of X-ray studies that salts exist in the ionic form even in the solid state, won universal acceptance for the basic principles of the theory of ionization. However, modifications were necessary in the Arrhemius theory.

Below: Six of the fourteen Frick "ECLIPSE" compressors installed in Sperry Engineering Test Department.



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The underlying cause of almost all the weaknesses in Arrhemius' theory is that he assumed the mobility of ions in an aqueous solution at a given temperature was a constant, independent of ionic concentration. However, the experiments of Hittorf and others on transport numbers seemed to contradict this assumption, at least for a strong electrolyte. When experiments with concentrated solutions of strong electrolytes indicated an apparent degree of ionization of more than 100%, an absolute impossibility, it became obvious that a correction was needed in the theory of ionization. This correction is the Debye-Hueckel theory, proposed in 1923 and further corrected by Onsager in 1927. This theory takes into consideration inter-ionic forces which make the solution of a strong electrolyte and, to some extent, even the solution of a weak electrolyte vary from the ieal solution. According to the Debye-Hueckel theory, every ion may be considered to be surrounded by an ionic atmosphere of opposite sign; in other words, in equilibrium, there will be around a given ion an excess of ions of opposite sign so that an equal charge of opposite sign opposes the charge of the given ion. These inter-ionic forces, even in equilibrium, will have an effect on the freezing point, boiling point, osmotic pressure, and other properties of any electrolyte, although in cases of a weak electrolyte the effect is negligible. When the equilibrium of the solution is disturbed by an electric current, the effects of the ionic atmosphere are even more important. As an ion moves in response to a current, the

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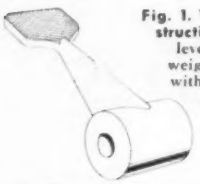

Fig. 1. Traditional Construction. Machine foot-lever, 10 inches long, weighs 6 pounds. Cost with broached keyway is $1.15.

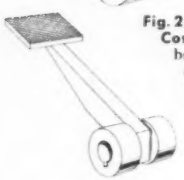

Fig. 2. Simple Steel Design Costs 41% Less. Can be built by the shop with only saw and shears. Weighs 2.7 pounds. Costs 68¢ complete with keyway.

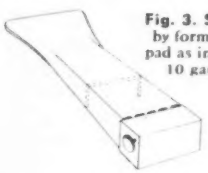

Fig. 3. Saves 53% Cost by forming lever arm and pad as integral piece from 10 gauge metal. Weighs 2.5 pounds. Costs 54¢.

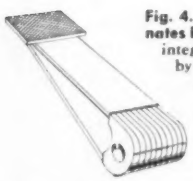

Fig. 4. Saves 73%, Eliminates Broaching. Hub with integral key is produced by stacking stampings in assembly. Arm is 10 gauge, brake formed and welded to hub. Cost is only 31¢. Weighs 2.2 pounds.

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ionic atmosphere is disturbed; the atmosphere will be denser behind the ion than in front of it and as a result a force which opposes the motion of the ion results. Also, there will exist a frictional force caused by *electrophoresis*, the motion of the solvent molecules as a result of being stricken by ions; as there are more ions of opposite than of like sign about a given ion and opposite ions strike the solvent molecules the most, the motions of the solvent molecules opposes the path of the given ion. The friction due to electrophoresis is additive to the friction caused by the viscosity of the solvent. Consideration of the forces created by the ionic atmoshere explains satisfactorily many quantitative and qualitative defects in the Arrhemius theory.

The Debye-Hueckel and Onsager theories lead to a complicated equation. This equation in its very simplest form as applied to a uni-univalent electrolyte is: $\Lambda = \Lambda_0 - (A + B\Lambda_0)\sqrt{c}$

where is the equivalent conductance of the solution, is the limit of the equivalent conductance of the electrolyte, A and B are complicated constants which depend on the temperature and nature of the solvent, and C is the concentration in moles. The Debye-Hueckel-Onsager equation is an expansion of the earlier Kholransch's law, which states that the equivalent conductance of a strong electrolyte in very dilute solutions is a linear function of the square root of the contration, or: $\Lambda = \Lambda_0 - A'\sqrt{c}$

Where A' is another constant depending on the nature of the solvent and the temperature and C is the concentration in normals.

The Onsager equation was still not perfect. There were two noticeable faults beyond the limits of experimental inaccuracy. The first was that some salts gave conductances that were too large at relatively high concentrations, although values at lower temperatures agreed with the theory. Shedlovsky in 1932 corrected the Onsager equation by the addition of three empirical constants. For a uni-univalent electrolyte, the Shedlovsky equation is:

$$\Lambda_0 = \frac{\Lambda + A\sqrt{c}}{1 - B\sqrt{c}} - C_c - D_c \log c + E c^2$$

Onsager equation by the addition of three empirica constants. For The other case is where the equivalent conductance is a linear function of the square root of the concentration but the conductance is less than required by the theory. This discrepancy is caused by the fact that Onsager assumed complete dissociation. Corrected for incomplete dissociation, the equation is:

$$\Lambda = \alpha\left[\Lambda_0 - (A + B\Lambda_0)\sqrt{\alpha c}\right]$$

It will be noticed that is no longer exactly a linear function of , but that the term , in which is less than one, will make the graph slightly concave.

Important Rules and Concepts

Very important are the three general rules of anodic oxidation in an electrolytic cell:

(1) If the anode is a base metal, it will be oxidized to form ions which go into solution.

(2) If the anode is a noble metal and the anion is a simple non-metallic ion, the anion will be reduced to a free non-metal.

(3) If the anode is a noble metal and the anion contains non-metallic elements in their highest oxidation number, hydroxyl ions are discharged.

In the second case, there may be a secondary reaction which the substance set free reacts with the water to form comlexions. In the third case there is always a secondary reaction in which water and oxygen are formed.

Another important fact is that the conductance of a given aqueous solution increases as the temperature increases. The increase in conductance is equal to roughly 2% per degree centigrade, the same rate at which the viscosity of water decreases. It thus seems that the increase of conductivity is a result, primarily, of the decrease in the internal friction of the solution.

The two forces of solution tension and solution pressure must be understood to explain many observations. Solution tension is a tendency of electropositive metals to go into solution in the form of a cation, leaving a negative charge on the undissolved metal; the negative charge on the metal acts to draw back many of the

Electronics Research Engineer Irving Aine records radiation antenna patterns on Lockheed's Radar Range. Twenty-two foot plastic tower in background minimizes ground reflections, approximates free space. Pattern integrator, high gain amplifier, square root amplifier and logarithmic amplifier shown in picture are of Lockheed design.

Jim Hong, Aerodynamics Division head, discusses results of high speed wind tunnel research on drag of straight and delta wing plan forms with Richard Heppe, Aerodynamics Department head (standing), and Aerodynamicist Ronald Richmond (seated right). In addition to its own tunnel, Lockheed is one of the principal shareholders in the Southern California Cooperative Wind Tunnel. It is now being modified for operation at supersonic Mach numbers.

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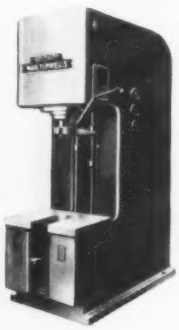

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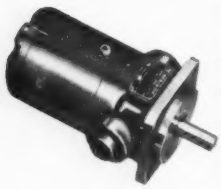

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ions and cause them to return to the metal and an equilibrium is reached. Solution pressure is the characteristic condensation of ions on any surface due to the continuous bombardment of the surface by the ions in their heat motions as the ions start to condense, they carry a positive charge to the surface of the substance and, therefore, very quickly charge it up to a potential such that no more positive ions can reach the surface. Thus equilibrium is also reached in solution pressure.

When a metal is immersed in a solution of its salts the two tendencies of solution tension and solution pressure oppose each other. An equilibrium is established between the sending of ions into solution and the precipitation of ions from solution. This equilibrium is determined by the nature of the metal, the form in which it ionized, the charge on the metal which pulls the ions back, the temperature, and the concentration of ions in extent, leaving a negative charge on the electrode. Gaseous elements, such as chlorine and oxygen also ionize to some extent in solution, yielding negative ions and leaving the electrode (usually platinum gauze with a mono-molecular layer of absorbed gas with a positive charge.) This ionization does not take place directly when the gas is dissolved in water, only when it is first absorbed.

This brings us to the concept of electrode potential. Equilibrium will be reached between solution pressure and solution tension when the difference in potential between the metal and gas and the solution of ions is so large that an ion has just enough energy to transport a unit positive charge from the zinc to the solution; the conditions which are involved in determining this point have already been mentioned.

From a table of standard E. M. F.'s, one can compute the decomposition voltage of a compound in a completely reversible electrolysis reaction. For example, if an approximately molar solution of $ZnBr_2$ is electrolyzed using platinum electrodes, the electrodes will become zinc and bromine electrodes as soon as decomposition starts. As the reaction is reversible, the E. M. F. needed to decompose $ZnBr_2$ is the difference between the standard E. M. F.'s of zinc and bromine. From the electrochemical series, we find that zinc has a standard E. M. F. of 0.76 volts and bromine has one of -1.06 volts. Therefore, the decomposition voltage, the minimum E. M. F. needed to decompose $ZnBr_2$ is 1.82 volts. When the applied E. M. F. is less than this, there will be only an extremely slight current flowing and no noticeable decomposition will take place. When the decomposition voltage is reached, the electrolytic cell becomes a voltaic cell which opposes the applied E. M. F. so that Ohm's law for an electrolytic cell becomes I=E-e/R, where E is the applied E. M. F. and e the counter E. M. F. At first the back E. M. F. is equal to the decomposition voltage, but, as the applied E. M. F. rises, the counter E. M. F. or E. M. F. of polarization also rises. The fact that a substance will not decompose until a certain applied potential is reached is important in controlling reaction and separating materials.

In cases where the electrode reaction is not completely reversible, the decomposition potential is not dependent on the standard E. M. F. of the substance being dissociated.In some cases the counter E. M. F. is due almost entirely to *concentration polarization.* This is the change in the concentration of the electrolyte in the immediate neighborhood of the electrodes. In such cases—for example, in the electrolysis of $CuSO_4$ between pure copper electrodes —stirring the solution of raising the temperature reduce the counter E. M. F. by making the concentration more constant.

Chemical polarization is found in the electrodeposition at the cathode of certain metals—iron, nickel, and cobalt—where the polarization is to a much greater degree than can be accounted for by concentration polarization. This condition is probably a result of the fact that the electrode process consists of several successive reactions and because one or more of these reactions cannot take place rapidly enough, under the given conditions, to maintain the various substances concerned near their equilibrium concentration. In favor of this view is the fact that chemical polarization decreases with a rise in temperature which increases the speed of

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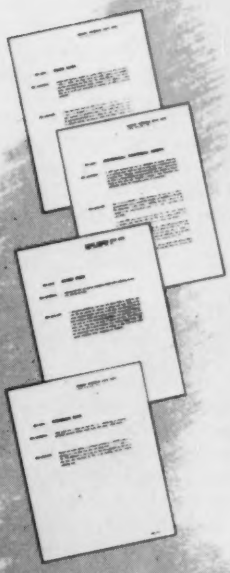

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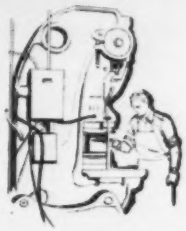

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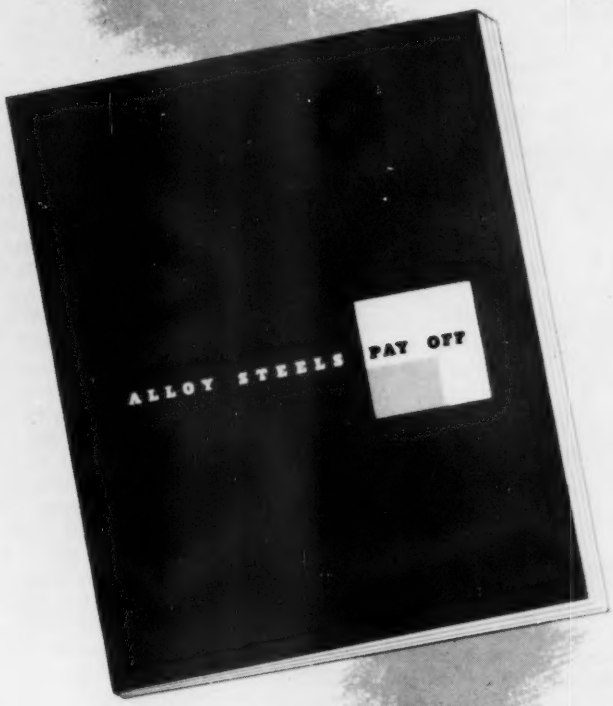

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chemical reactions. In general, it may be stated that where one or both electrodes are functioning in a manner not completely reversible, as in the above two cases or when oxygen is formed from the hydroxyl group, the decomposition voltage cannot be predicted, even approximately from the electrochemical series but must be found by experiment.

It has been discovered that whenever the products of electrolysis of an acid or base between platinum electrodes are H_2 and O_2 only, the decomposition voltage is about 1.7 volts. This indicates that the electrode processes are probably always identical. It has also been noted that the decomposition voltage of an HC1 solution between platinum electrodes increases with dilution until about 1.7 volts is reached, at which point the products of electrolysis become only H_2 and O_2 and that beyond this point decomposition voltage does not increase at all with dilution. As oxygen is given off in the electrolysis of water, the reaction is not completely reversible. However, the E.M.F. of a hypothetical reversible reaction in which oxygen is evolved has been computed, by the relation between free energy and E.M.F., to be 1.2 volts. Since in a platinum electrode cell where the current density is low, the liberation of hydrogen is reversible and such a cell has a decomposition voltage of 1.7, the oxygen electrode (O_2 absorbed on platinum) is irreversible to the extent of about 0.5 volt, or the oxygen is liberated on the platinum at an overvoltage of 0.5 volt. This overvoltage increases slightly with current density and also depends on the nature of the anode material. There is no completely acceptable explanation of oxygen overvoltage, but it is assumed by many scientists to be the difficulty of creating monatomic oxygen out of O_2 by catalyst and electricity.

In cases where a solution containing metallic ions and hydrogen (actually hydronium) ions is electrolyzed, it is evident that the cation which is liberated is the one that will give rise to the smaller electrode E.M.F. and thus oppose the current the least. It should also be noted that when the liberation of a given ion diminishes its concentration, the cathode E.M.F. will gradually increase until it reaches a value corresponding to the liberation of the other ion. It would seem as if calculating the E.M.F. that has to be overcome before an ion at a given concentration can be liberated will tell which ion will be discharged. However, such calculations are not a true indication in many cases, for the deposition of even the slightest amount of the metallic ions on the platinum cathode will turn it into a cathode of the other metal. There is always such a deposition to a very slight extent, even with alkali metals. On the altered cathode, the hydrogen reaction is not completely reversible and there is hydrogen overvoltage which, in the case of metals as high in the electrochemical series as zinc, may be so great that it is easier to liberate the metallic ions than the hydrogen ions. Naturally, when the cathode is originally of the same metal as the ions or of another base metal, the chances of the metallic ions being deposited are greater. Indeed, sodium can be obtained by electrolyzing a sodium chloride solution with a mercury cathode.

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In the electrolysis of molar HC1 with platinum electrodes, the back-E.M.F. will be 1.36 volts. If $FeCl_3$ is added to the cathode solution, the cathode process will change from the reduction of H^+ to hydrogen molecules to the reduction of Fe^{+++} to Fe^+, for the E.M.F. of a ferrous-ferric electrode is lower than that of a hydrogen electrode, —0.78 compared to 0. As long as any appreciable amount of ferric ions are present, the sole cathode process will be the reduction of the ferric ions and there will be no hydrogen gas evolved. The total back-E.M.F. of the cell will be —0.78—(—1.36) =0.58 volts, much less than the original back-E.M.F. In this case the ferric salt is said to be a depolarizer for the cathode. Adding a ferrous salt to the anode brings about oxidation of the ferrous ions with no evolution of either chlorine or oxygen and also a further drop in the back-E.M.F. Thus the anode is depolarized. Naturally, a depolarizer would normally be used only in one compartment to cut down the back-E.M.F. while allowing the reaction at the other

electrode to go on undisturbed. Electrochemical reduction and oxidation, including such processes as the two just described with salts of iron are very important in industry. Using them, products can be obtained in a more direct manner and in a purer state than otherwise.

If there is only a slight difference in the E.M.F.'s or polarization of two metallic ions, both will sometimes plate out. It has been found that the addition of potassium cyanide to certain pairs of metallic ions will change their E.M.F.'s so that they plate out to form an alloy.

Electrolysis would be a good deal easier to understand were it not for the formation of complex ions such as hydronium, ferricyanide, and argentammine. These complex ions may be noted in cases where the addition of a substance increases rather than decreases the solubility in water of another substance having a common ion. In fact, the solubility of any sparingly soluble salt can be increased by the addition of any substance which is able to remove the simple ions is the form of complex ions. Some substances dissociate to form both complex and simple ions, as in the case of cadmium iodide which ionizes according to the equation in dilute solutions: As the solution becomes more concentrated, the compound begins to break up partially according to the following equation:

$$2CdI_2 \quad Cd^{++} + CdI_4$$

When the concentration is high enough, there are so many CdI_4 ions that under the influence of an electric current, the apparent transport number of cadmium becomes minus, meaning that more is flowing to the anode as CdI_4 than is flowing to the cathode as Cd^{++}.

III. VARIOUS ELECTROLYTIC CELLS

The coulometer is a very interesting form of electrolytic cell which is used as an instrument for determining the quality of electricity which flows through a circuit. The silver coulometer used in determining the faraday and in extremely precise experiments is the most accurate coulometer. It consists of an anode of pure silver with a large area so that the current density does not exceed 0.2 amperes per square centimeter. The anode is inserted in a porous cup or surrounded by a glass vessel to prevent particles of silver from flaking off and falling on the cathode. The cathode is a platinum cup of area so that current density is less than 0.02 amps/cm.^{2}. The electrolyte is silver nitrate solution. The silver coulometer is connected in series in a circuit and the current causes silver to deposit out on the cathode. The weight of the deposited silver will give the amount of current within 0.004% if the proper precautions are taken. A simplified silver coulometer determines the amount of silver dissolved in a potassium nitrate solution when a current is passed through it; it gives results accurate to 0.1%. Other coulometers use iodine, copper, sodium, and mercury as the element which is dissolved and deposited.

Another interesting cell is the one used in determining transport numbers by the Hittorf method. The simplest Hittorf apparatus in an H-shaped tube with stopcocks at the bottom of both vertical tubes and electrodes made of various materials depending on what is being tested and how accurate the results must be. The apparatus is filled with the experimental solution and the electrodes are connected in series to a coulometer and a source of current. 0.01 to 0.02 ampere is the amount passed for two to three hours. At the conclusion a sufficient quantity of solution, containing all that is believed to have changed in concentration is run off slowly from each limb and analyzed. Then a further portion is removed to serve as a control; this portion should have the same concentration as the original solution. Analysis of the electrode solutions and measurement of the metallic deposit in the coulometer give enough data to compute transference numbers. More complicated and accurate equipment has been made, including cells which indicate the transport of solvent molecules by indicators, membranes, or moving boundaries.

There are hundreds of other types of electrolyte cells, some simple as the one in which copper is purified and some extremely complicated as the various nitrobenzene reduction cells. Only a few moderately complicated cells have been discussed here. Indeed, electrolysis is such a great field, volumes could be written without completely covering it.

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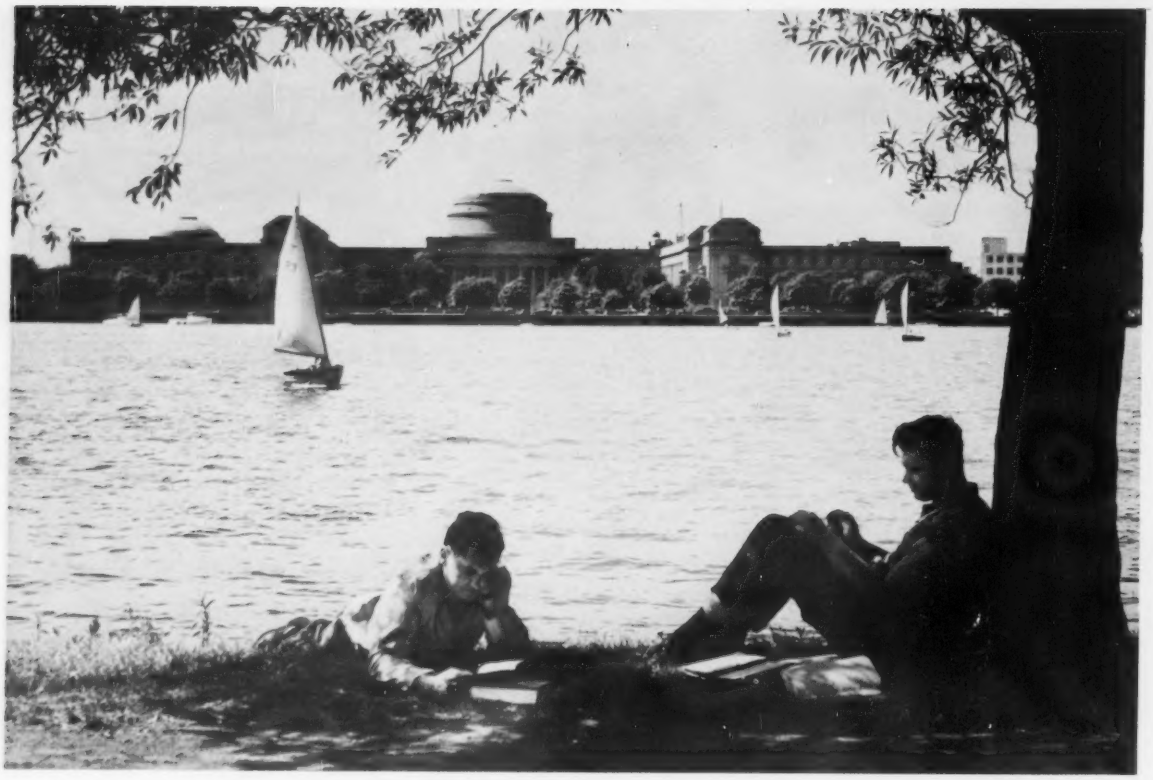

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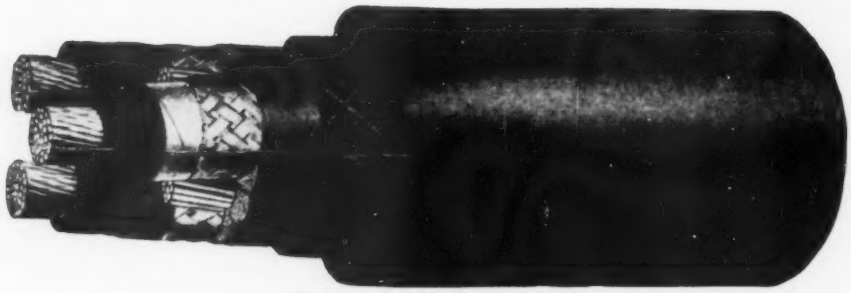

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Other activities of the Computer Systems Division include a program of development of an advanced type of digital computer for military applications and operation of the company's own computing center, consisting of extensive, general-purpose computing equipment.

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Only a few short years ago

the helicopter was thought to be a "stunt" machine — amazing and amusing, and not particularly important. Events in Korea changed that idea — fast! This fledgling among aircraft performed "impossible" military assignments, spectacularly successful missions of mercy. Helicopters came into their own.

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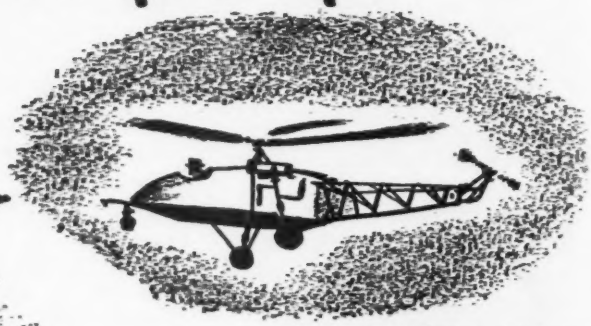

In 1939, the VS-300 with Igor Sikorsky at the controls made the first practical helicopter flight in the United States. Hundreds of later Sikorsky's were delivered for service in World War II.

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Graduate study may be pursued in Textile Technology, Ceramics, Sanitary Engineering, and in most of the above professional Courses. The Master's and Doctor's degrees are offered in most of these fields.

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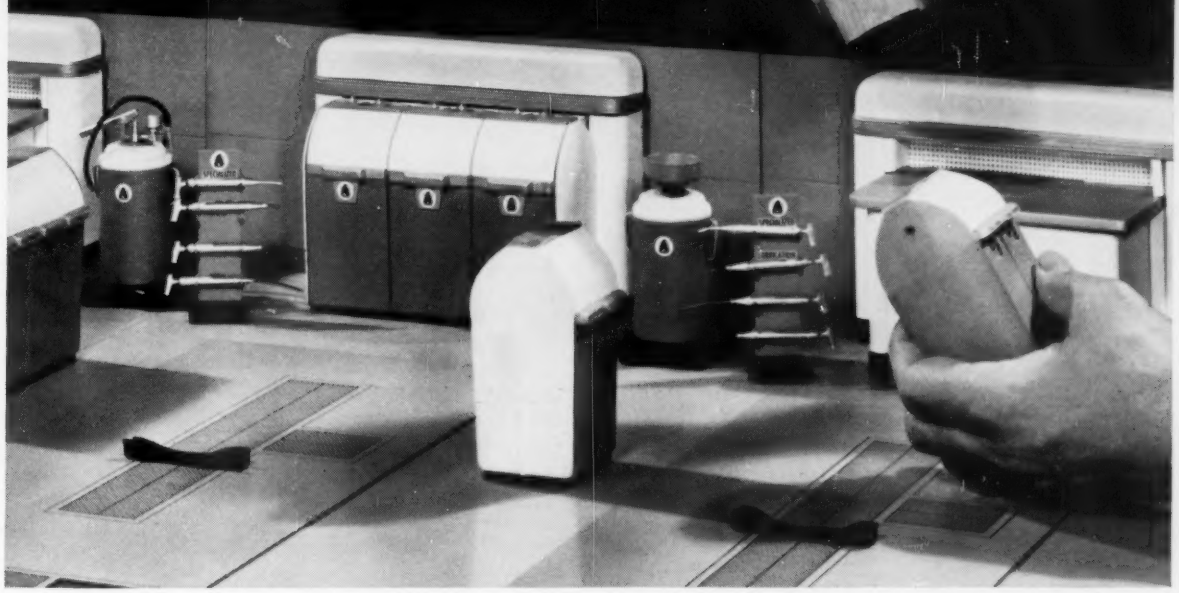

Alemite sets up scale models of their service station equipment on the customer's own floor plan—photographs them—and portrays the new custom-built station ready for action

SALESMEN don't just pull lube racks, grease pumps and other service station equipment out of a sample case. They're far too big—far too bulky. Besides, final location and arrangement count heavily in how well they are going to work out.

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It works this way. The salesman sends in a rough sketch of the space available, with windows and columns marked. Experts fit exact replicas of racks, lifts, and other equipment to the plan, then put the camera to work. The customer pictures his new station—modern, efficient, handsome—and the sale is well on its way. It's an idea for any company with bulky products to sell. Photography is a great salesman for any business, large or small. And it's very much more. It works in all kinds of ways to save time, cut costs, reduce error and improve production.

Graduates in the physical sciences and in engineering find photography an increasingly valuable tool in their new occupations. Its expanding use has also created many challenging opportunities at Kodak, especially in the development of large-scale chemical processes and the design of complex precision mechanical-electronic equipment. Whether you are a recent graduate or a qualified returning service man, if you are interested in these opportunities, write to Business & Technical Personnel Dept., Eastman Kodak Company, Rochester 4, N.Y.

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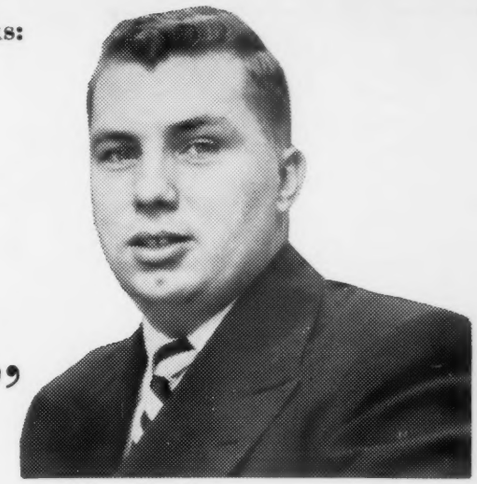
JOHN B. NOLTE, Purdue University '54, asks:

"What is G.E.'s Manufacturing Training Program?"



The Manufacturing Training Program at General Electric is a program of basic training for manufacturing leadership, including planned rotational work assignments and related classroom study for outstanding young men who are interested in a career in manufacturing. It was organized to meet the increased demand for effective manufacturing leadership and technical "know how," in line with the expansion and development of the Company's operations by developing trained men to fill future key positions in the organization.

Who is eligible for this program?

In general, the Program is open to college graduates with degrees in engineering and science, and a limited number of business administration and liberal arts graduates. We are looking for outstanding young men with sound educational backgrounds, well-balanced personalities, demonstrated thinking abilities, and having the potential to develop toward top level responsibility in key assignments.

How long is the program?

The normal length of the Program is three years. Assignments are normally 6 months in duration and provide experience opportunities in diversified manufacturing operations. Geographical moves occur at annual intervals.

What type of work assignments are made?

Work assignments are provided in all phases of manufacturing and related functions so that each man will acquire knowledge of manufacturing engineering, including manufacturing methods and techniques, shop operation, production control, personnel administration, labor relations, engineering activities, sales and manufacturing co-ordination, and general business administration.

In addition to job assignments, related study courses cover such subjects as Company organization, manufacturing operations, labor and personnel relations, business administration, law and relationships between manufacturing and other functions of the business. Progress on the job and in classroom work is carefully observed and reviewed periodically with each man to assist him in his career.

What happens after training is completed?

After completing the training program, graduates are placed in operating departments and divisions throughout the Company in positions where leadership and initiative are needed. All placements are made in relation to the aptitudes, abilities, and interests of the graduates.

At General Electric, manufacturing operations involve the administration and supervision of activities of more than 100,000 men and women in more than 100 plants, who are involved in the making of some 200,000 different products.

The wide scope of these activities, the great variety of products, and the diversity of manufacturing activities offer limitless opportunities and exciting challenges to college graduates today.

Manufacturing training is a foundation for leadership—and an opportunity to build a satisfying, rewarding career in one of America's most important industries.

If you are a graduate engineer, or a graduate with definite technical inclinations that include an interest in the career possibilities in manufacturing, see your college placement director for the date of the next visit of the General Electric representative on your campus. Meanwhile, for further information on opportunities with General Electric write to Manufacturing Training Services Section, Bldg. 36, General Electric Company, Schenectady 5, New York.

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